















U. S. DEPARTMENT OF COMMERCE

R. P. LAMONT, Secretary,

BUREAU OF STANDARDS

GEORGE K. BURGESS, Director

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Miscellaneous Publication No. 115

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# ANNUAL REPORT

OF THE

# DIRECTOR OF THE BUREAU OF STANDARDS

TO THE

# SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1930



UNITED STATES  
GOVERNMENT PRINTING OFFICE  
WASHINGTON : 1930



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ELECTRICITY	WEIGHTS & MEASURES	HEAT & POWER	OPTICS	CHEMISTRY
F.O.Crittenden 210 East 2	H.W.Pearce 9 F.S.Holbrook 80 215 South	H.C.Dickinson 208 West 12	C.A.Skinner 415 South 125	E.W.Wa 215 Ch
1 Resistance Measurements F. Wenner 118 East 23	1 Length L.V.Judeon 209 South 232	1 Thermometry Miss J. Russ 205 West 74	1 Spectroscopy W.F. Meggers 212 South 84	1 Paints & Pigments P.W. Sh 417 Ch
2 Inductance & Capacitance H.L. Curtis 217 East 29	2 Mass A.T. Pienkowski 101 South 81	2 Pyrometry H.T. Veneel 210 West 58	2 Polarimetry F.J. Bates 306 West 22	2 Detergents F.W. Sh 403 Ch
3 Electrical Instruments H.P. Brooke 109 East 25	3 Time R.E. Gould 218 South 33	3 Heat Measurements E.F. Mueller 202 West 48	3 Colorimetry I.G. Priest 400 South 83	3 Organic Chemistry C.E. Wa 303 Ch
4 Magnetic Measurements R.L. Sanford 114 East 31	4 Capacity & Density E.L. Peffer 200 South 108	4 Heat Transfer M.S. Van Dusen 201 West 46	4 Optical Instruments I.C. Gardner 407 East 103	4 Metal Analysis Stand G.L. F. 317 Ch
5 Photometry J.F. Meyer 311 East 32	5 Gas Measuring Instruments H.S. Bean 211 NW 107	5 Cryogenic Laboratory F.G. Erickwede 22 Low Temp. 184	5 Radiometry W.W. Goblantz 119 South 71	5 Reagent Apparatus Store K. Hoch 102 Ch
6 Radio J.H. Dellinger 207 Radio 42	6 Thermal Expansion W. Souder 108 South 78	6 Fire Resistance S.R. Ingberg 286 Ind. 78	6 Atomic Physics, Radium, X Rays F.L. Mohler 312 East 203	6 Electrochemistry W. Blum 117 Ch
7 Underground Corrosion K.H. Logan 207 East 44	7 Weights & Measures Administration R.W. Smith 210 South 222	7 Automotive Power Plants R.K. Cummings 107 West 144	7 Photographic Technology R. Davis 338 Ind. 18	7 Gas Chromatography K.R.W. 203 Ch
8 Safety Standards M.G. Lloyd 209 East 36	8 RR Scales & Cars H.W. Rosser, Field Service. (F.S. Holbrook 215 South 80)	8 Friction & Lubrication M.D. Hasey 108 West 87	8 Interferometry O.O. Peters 112 South 76	
9 Electrochemistry G.W. Vinal 404 East 93	9 Gages D.R. Miller 202 NW 153			
10 Telephone Standards F.A. Wolff 410 East 38				

  

OFFICE
H.D. Hubbard 315 South 4
PLANT
O.L. Britt Power Plant 5
SHOPS
O.O. Lange 25 North 34

## BUREAU OF STANDARDS

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DEPARTMENT OF COMMERCE,  
BUREAU OF STANDARDS,  
*Washington, July 1, 1930.*

The honorable the SECRETARY OF COMMERCE.

DEAR MR. SECRETARY: I submit herewith a brief report upon the work of the Bureau of Standards during the fiscal year ended June 30, 1930. The various outstanding accomplishments are grouped according to the subjects for which the Congress had made specific appropriations.

### GENERAL ACTIVITIES

*Organization.*—The present organization of the bureau is shown by the chart on the opposite page.

*Cooperation.*—In addition to the several hundred governmental, scientific, technical, and industrial organizations which help to make the bureau's work effective, 38 industrial associations and individual firms take part in the bureau's research program directly through 97 research associates stationed in the various laboratories.

*Personnel.*—In September, 1929, R. M. Hudson, assistant director in charge of commercial standardization, resigned to accept the position of technical adviser to the New England Council with headquarters in Boston. As of July 1, 1930, J. S. Taylor will be promoted to chief of the division of building and housing. Mr. Taylor has been connected with this division since its establishment in 1921, and has served as its acting chief since 1928.

The regular staff at the close of the fiscal year numbered 1,055 employees. With miscellaneous assignments, the grand total was 1,161 persons, an increase of 89 as compared with last year. The turnover was 22.2 per cent. There were 645 promotions and reclassifications to higher grades, and the average salary, \$2,450, increased by \$37.

The contributions of members of the bureau's staff to scientific and technical progress have received public recognition in several cases. The degree of doctor of science was conferred on W. W. Coblenz by the Case School of Applied Science for his contributions in the field of radiometry, while the same degree was conferred by Stevens Institute of Technology upon N. S. Osborne in recognition of his research work on the physical properties of ammonia and steam. The director of the bureau was elected an honorary member of the Imperial Japanese Society of Mechanical Engineers on the occasion of the International Engineering Congress at Tokyo. E. C. Crittenden is serving as president of the United States National Committee of the International Commission on Illumination. A gold

**DIRECTOR'S OFFICE**  
 DIRECTOR, GEORGE F. BURGESS  
 Secretary to Director, Miss D. E. Klingebury  
 314 South tel. br. 1

**RESEARCH AND TESTING**  
 Assistant Director L.J. Briggs 101 West 224

**COMMERCIAL STANDARDIZATION**

ELECTRICITY	WEIGHTS & MEASURES	HEAT & POWER	OPTICS	CHEMISTRY	MECHANICS & SOUND	ORGANIC & FIBROUS MATERIALS	METALLURGY	CLAY & SILICATE PRODUCTS
E.O.Ottenden 210 East 2	H.W.Pearce 9 F.S.Holbrook 90 216 South	H.O.Dickinson 208 West 12	O.A.Skinner 415 South 126	E.W.Washburn 215 Chem. 3	L.J.Bridge 101 West 224	R.E.Bailey 101 Ind. 186	H.S.Rawdon 114 NW 18	Whiteware P.H.Geller 141 Ind. 15
1 Resistance Measurements F.Wanner 118 East 28	1 Length L.V.Judson 200 South 232	1 Thermometry W.J.Dane 203 West 74	1 Spectroscopy W.F.Magers 212 South 84	1 Paints,Varnishes, & Bitum. Mixes. F.R.Walker 417 Chem. 47	1 Engineering Instruments & Mech.Appliances W.F.Stutz 104 West 102	1 Rubber P.L.Cornelley 227 Ind. 13	1 Optical Metallurgy H.S.Rawdon 105 NW 206	1 Whiteware P.F.Geller 141 Ind. 147
2 Inductance & Capacitance H.L.Ourtis 217 East 29	2 Mass A.T.Plankowsky 101 South 91	2 Pyrometry R.T.Wensel 210 West 59	2 Polarimetry F.J.Setze 308 West 22	2 Detergents, Cement, Corro- sion, etc. F.W.Seither 403 Chem. 8	2 Sound Paul R. Nepl 305 NW 227	2 Textiles W.O.Appel 106 Ind. 150	2 Thermal Metallurgy R.L.Dowdell 102 NW 209	2 Glass A.N.Pinn 25 Ind. 149
3 Electrical Instruments H.P.Prooke 109 East 25	3 Time R.E.Could 218 South 33	3 Heat Measurements E.P.Mueller 202 West 46	3 Colorimetry I.O.Priest 400 South 03	3 Organic Chemistry J.O.E.Waters 303 Chem. 82	3 Aeronautic Instruments W.O.Broschacher 311 NW 226	3 Paper B.W.Scribner 107 Ind. 137	3 Mechanical Metallurgy W.H.Swanger 110 NW 95	3 Refractories R.A.Hotindl 248 Ind. 147
4 Magnetic Measurements H.L.Sanford 114 East 31	4 Capacity & Density E.L.Paffer 200 South 106	4 Heat Transfer W.S.Van Duse 201 West 48	4 Optical Instruments I.O.Oaydun 407 East 103	4 Metal & Ore Analyse Kotel & Sons 317 Chem. 138	4 Aerodynamic Physics H.L.Dryden Wind Tunnel 129	4 Leather R.C.Bosker 319 Ind. 134	4 Chemical Metallurgy L.Jordan 103 Chem. 117	4 Enamels W.N.Harriote 147 Ind. 147
5 Photometry J.F.Mayer 311 East 32	5 Ore Measuring Instruments H.S.Pean 211 SW 107	5 Cryogenic Laboratory F.O.Bricksedge 22 Low Temp. 184	5 Radiometry W.W.Coblentz 119 South 71	5 Reagents, & Apparatus, & Storeroom K.Wichers 103 Chem. 114	5 Engineering Mechanics H.L.Whittemore 241 Ind. 122	5 Experimental Foundry C.W.Seager, Jr. 3 NW 211	5 Heavy Clay Products R.T.Stull 148 Ind. 147	5 Cement; Concrete Materials J.Tucker, Jr. 157 Ind. 15
6 Radio J.H.Dellinger 207 Radio 42	6 Thermal Expansivity W. Souder 108 South 79	6 Fire Resistance S.H.Ingber 286 Ind. 79	6 Atomic Physics, Radium, & Rays F.L.Mohler 312 East 203	6 Electrochemistry (Plating) K. Blum 117 Chem. 118	6 Electrochemistry (Plating) K. Blum 117 Chem. 118			6 Masonry Construction O.E.Parsons 161 Ind. 15
7 Underground Corrosion E.H.Logan 207 East 44	7 Wts. & Mass. Loss Administration R.W.Smith 210 South 222	7 Automotive Power Plants R.S.Cummings 107 East 144	7 Photographic Technology R.Davis 339 Ind. 18	7 Gas Chemistry E.R.Weaver 203 Chem. 98				7 Line & Gypsum J.A.Murray 285 Ind. 151
8 Safety Standards W.O.Lloyd 209 East 36	8 RR Gases & Cars H.W.Roeser, Field Service. (F.S.Holbrook, 216 South 80)	8 Friction & Lubrication W.O.Harvey 109 East 97	8 Interferometry O.O.Peters 112 South 78					8 Stone D.W.Kessler 193 Ind. 15
9 Electrochemistry O.W.Vinell 404 East 93	9 Gases O.S.Miller 202 SW 153							
10 Telephone Standards F.A.Wolff 410 East 38								

OFFICE, PLANT, AND SHOPS

SIMPLIFIED PRACTICE	BUILDING & HOUSING	SPECIFICATIONS	TRADE STANDARDS
Edwin W. Kly 353-B Ind. 280	J.S. Taylor, Acting 353 Ind. 281	A.S. Walliester 310 South 55	I. J. Fairchild 310 South 68
1 Stone, Clay and Glass H.R. Colwell 361 Ind. 287	1 Building Codes O.N. Thompson 357 Ind. 283	1 Certification - Producer Contacts R.A. Martino 310 South 55	1 Wood, Wood Products, Paper, Rubber, Oils H.R. Steidle 404 South 175
2 Wood, Textiles and Paper Geo. Schuster 359 Ind. 284	2 Building Practice & Housebuilders' Problems V.B. Phelps Acting 347 Ind. 287	2 Labeling - Consumer Contacts C.S. McAllister 310 South 65	2 Metal Products I.J. Fairchild 310 South 68
3 Metal Products & Construction Materials P.H. H. Dunn 359 Ind. 284	3 City Planning & Zoning J.S. Taylor 353 Ind. 281	3 Directory of Specifications O.V. Ingole 310 South 55	3 Textiles and Ceramics I.J. Fairchild (acting) 310 South 68
4 Containers W.E. Breitbarth 363 Ind. 285	4 Construction Economics J.R. Siggleman 349 Ind. 288	4 Encyclopedia of Specifications O.A. Verdes 310 South 55	4 Ceramic Products and Cement O.W. Frey 404 South 175
5 Promotion and Adhesives A.E. Galt 399 Ind. 289	5 Mechanics Liens O.H. Wheeler 345 Ind. 288		

LIAISON WITH AERONAUTICS BRANCH  
 DEPT. OF COMMERCE  
 L.J. Briggs  
 101 West 224

LIAISON WITH FEDERAL SPECIF. BOARD  
 J.R. Fellows  
 316 South 185

**OFFICE, PLANT, AND SHOPS**

OFFICE	PLANT	SHOPS
H.O. Hubbard 315 South 4	O.L. Britt Power Plant 5	O.O. Lange 25 North 34
1 Finance O.L. Thomas 305 South 52	1 Power Plant L.J. Mollweine Power Plant 24	1 Instruments & Machine Shops O.O. Lange 25 North 34
2 Personnel W.C. Fessell 308 South 180	2 Buildings & Grounds F.A. Peters Power Plant 95	2 Woodworking Shop L.R. Downs Far West 50
3 Purchases & Stores G.R. Taneman 301 NW 180	3 Wiring & Electric Work A.A. Ludeig Far West 48	3 Glass Blowing Shop E.O. Sperling 304 NW 54
4 Property & Transportation F.A. Ross 301 NW 188	4 Plumbing and Piping E.C. Koch Far West 48	4 Glass Grinding Shop E.F. Webb 339 Ind. 121
5 Mails & Files H.W. Lamberson 419 South 80		5 Photographic Shop W.S. Rice 339 Ind. 18
6 Library A. Pantl 203 SW 76		6 Construction Shop J.K. Kirby 21 North 129
7 Information H.C. Boutell 300-B South 230		





medal was awarded to the Bureau of Standards for its part in the exhibit of the Department of Commerce at the Ibero-American Exposition held at Seville, Spain, in 1929.

*Visiting committee.*—The present personnel of the committee is: W. R. Whitney, John R. Freeman, Gano Dunn, S. W. Stratton, and Charles F. Kettering. The committee held one meeting at the bureau, advocating the establishment of a national hydraulic laboratory, the purchase of additional land, the making of desirable alterations to buildings, and preparing a patent policy.

*Hydraulic laboratory.*—An advisory committee on the design, scope, and problems of the National Hydraulic Laboratory, consisting of representatives of the interested Government departments and a number of prominent hydraulic engineers, has been appointed. Tentative designs are now receiving consideration. It is expected that the laboratory will be finished by July, 1931.

The new laboratory will have three principal functions: (1) It will carry out fundamental investigations on all types of hydraulic phenomena to increase the accuracy of flow coefficients and to extend our knowledge of these phenomena; (2) it will conduct model studies of proposed hydraulic structures to determine the form which is most effective and least expensive to build and maintain; (3) it will conduct routine tests on all kinds of hydraulic instruments, meters, and accessories, and develop and improve such equipment.

*International relations.*—The International Committee on Weights and Measures at its meeting in June, 1929, took definite steps toward putting electrical units on a new basis and decided also to take up the problem of the measurement of light. The action on electrical units followed exactly the recommendations made by the bureau to the International Advisory Committee on Electricity and approved by that committee. The effect will be to make the electrical units concordant with mechanical units as based on the fundamental centimeter-gram-second system.

A meeting of the Advisory Committee on Electricity was held June 23–25, 1930, in Paris. The bureau submitted recommendations on photometric units and methods, including a proposal that the complete radiator ("black body") at the freezing point of platinum be adopted as the primary standard of light.

Two members of the bureau's staff served as technical advisers to the American delegates at the first meeting of the International Technical Consulting Committee on Radio Communications held at The Hague in September, 1929. This committee, which is to meet at 2-year intervals, deals with scientific and engineering problems arising under the International Radiotelegraph Convention.

The first international steam-table conference held in London, July 8–12, 1929, and the second conference held in Berlin, June 23–27, 1930, at the time of the Second World Power Conference were attended by two representatives of the bureau. The first conference adopted a master steam table, with values and tolerances, which will serve as a gage to judge published tables for accuracy. Instead of the kilocalorie, as defined by the London conference, the bureau has suggested the use of the true joule and kilojoule as heat units, in conformity with existing laboratory practice.

For the Berlin conference a complete report of the bureau's work on heat content of saturated water and steam up to  $270^{\circ}$  C., and on latent heat of vaporization in the range  $100^{\circ}$  to  $270^{\circ}$  C., was available in printed form.

Three papers were presented at the World Power Conference at Berlin, June, 1930, entitled "Scientific Research in the United States on Gasoline Engines," "Volatile Liquid Fuels," and "Government Interest in the Advancement of Standardization."

Resistance thermometers have been intercompared at the National Physical Laboratory, the Physikalisch-Technische Reichsanstalt, and the Bureau of Standards, in connection with work on the international temperature scale.

Values obtained at four laboratories (National Physical Laboratory, Physikalisch-Technische Reichsanstalt, Nela Research Laboratory, and Bureau of Standards) for the melting point of palladium have been found to lie within a range of  $4^{\circ}$  C., thus justifying the adoption of  $1,555^{\circ}$  C. for the international temperature scale.

Standard cells have been exchanged with the national laboratories of Great Britain, Japan, and the Union of Socialist Soviet Republics.

A source of error in a mica condenser measured at the National Physical Laboratory and the Bureau of Standards was traced to damage received in transit, the actual capacitance measurements of the two laboratories being in good agreement.

The director of the bureau attended the World Engineering Congress held at Tokyo, Japan, in November, 1929, and presented a paper on precision machines and instruments for the measurement of length. In addition to presenting the paper and presiding over several sessions of the congress he served as one of the official delegates of the National Screw Thread Commission and eight other national bodies.

*Visitors.*—The bureau has been honored by many distinguished visitors from all over the world, among whom may be mentioned Profs. Masao Kamo and S. Jimbo and Dr. Seizo Saito, of Japan; Profs. Heinrich Barkhausen, Beno Gutenberg, Ludwig Prandtl, T. H. von Karman, D. F. Körber, and E. H. Schulz, and Dr. Karl Maybach, of Germany; Prof. Ernst F. Petritsch, of Austria; Dr. M. Chatelain, head of the Central Bureau of Weights and Measures; Dr. Richard Vieweg and Prof. E. A. Chudakov, of the Union of Socialist Soviet Republics; Drs. Tranquillo Zervi and Umberto Savoja, of Italy; Dr. Bengt Kjerman, of Sweden; Mr. Bernard Brull, of France; Prof. Robert K. Murphy, of Australia; Prof. H. Bolognini, of Argentina; Prof. P. H. Hermann, of Holland; and Prof. W. Baldwin Fletcher, of England.

In addition to these individuals, the officers and graduating students of the Japanese Naval Academy, the Japanese Lighting Mission, the American Society of Mechanical Engineers (in connection with their fiftieth anniversary celebration), a special delegation of professors and students from the University of Delft, Holland, the Society of Motion Picture Engineers, a delegation of Swiss electrical engineers and metallurgists, and many other groups have visited the bureau's laboratories. The records show visitors from such distant places as Calcutta; Formosa; Harbin; and Tashkent, Turkestan, besides practically every country in Europe and America.



*Weights and measures conference.*—The twenty-third meeting of the National Conference on Weights and Measures was held under the auspices of the bureau on June 3 to 6, 1930. Two important additions were made to the general specifications for weighing scales; antifriction elements must be used where necessary and provision made for adjusting the balance condition of scales. Minor changes were made in the codes for liquid-measuring devices and lubricating-oil bottles. A complete code for odometers was adopted in tentative form and will come up for review and final action next year. One amendment to the code for grease-measuring devices was adopted.

A beginning was made in the development of a code of specifications for automatic-indicating scales, and it is anticipated that this subject will be given consideration at several future meetings.

By resolution, the conference condemned the use of small-diameter, tall bottles with integral spouts and no vent for dispensing lubricating oil, and approved the use of a chemical treatment to reduce the dust from coal, provided the treatment does not increase the weight per ton by more than 30 pounds, and provided such coal is advertised as "chemically treated" coal.

Technical papers on many weights and measures subjects were presented, and a special demonstration of gasoline-metering devices was given for the benefit of the delegates.

*Conference of State utility commission engineers.*—The eighth annual conference of State utility commission engineers was held at the bureau on June 5 and 6. Committee reports were presented on rural electrification standards, depreciation and obsolescence, rate decisions, uniform types of rates, and charges for fire protection. The technical papers covered radio interference; submetering; trends in high-tension transmission practice; investigation of complaints by commissions; definitions in connection with utility appraisals; distribution extension rules applicable to electricity, gas, and water; improvements in rural telephone service; trends in urban transportation; future of electric railways; and a discussion of a questionnaire on gas-service standards.

*Conference on street and highway safety.*—The bureau took an active part in the national conference on street and highway safety called by the Secretary of Commerce, and submitted several recommendations for traffic control.

*Federal Fire Council.*—This organization was formed at a conference of Government representatives called by the Secretary of Commerce on April 3, 1930, to function in advisory and informative capacity on matters relating to fire prevention and protection arising in connection with Government activities. While the period has been required largely for organization and preparatory detail, several requests for assistance from departments and establishments have received attention.

*American Standards Association.*—The bureau has continued its close cooperation with this association. The bureau is sponsor for 81 standardization projects and is represented on 14 committees having for their object the formulation of American standards.



*National Screw Thread Commission.*—The activities of the commission have been directed principally along lines calculated to bring its screw-thread standards into wider and more effective use. The latest report of the commission (Bureau of Standards Miscellaneous Publication No. 89) has been subdivided into three sections and republished as separate pamphlets covering: I. Standard Threads; II. Special Threads; and III. Plain and Thread Plug and Ring Gage Blanks. These are intended primarily for shop use. They have also been submitted to industry, through the division of trade standards for acceptance as commercial standards.

*American Gage Design Committee.*—The report of this committee (Bureau of Standards Miscellaneous Publication No. 100) has met with wide acceptance and approval by manufacturers and users of limit gages. Its wide use has resulted in substantial savings in industry.

*Federal Specifications Board.*—This board, of which the Director of the Bureau of Standards is ex officio chairman, has promulgated its six hundred and fifty-first purchase specification. A large part of the research and experimental work on which these specifications are based is performed in the bureau's laboratories, and the chairmanships of many of the board's committees are held by members of the bureau's staff.

*Relations to Government departments.*—The bureau is authorized to receive funds for specific research projects from other departments, and in pursuance of this policy in the past year the bureau has received \$436,387 for the support of 37 projects representing work for 10 Government establishments. In addition, the usual consulting, specification, and testing work has been carried on for almost every branch of the Government.

*Publicity, bureau reports.*—The number of research papers published in the Bureau of Standards Journal of Research was 106. Including articles in the Journal, and all other papers in the regular series of the bureau, the total number of publications released during the year was 182. About 240 papers were published in outside journals. The Technical News Bulletin and the newly established Commercial Standards Monthly have been issued each month. The latter has attained a paid circulation of over 5,000. There have been released to the press 218 short accounts of interesting achievements. The fourth annual number of the Standards Yearbook was published in March.

*Testing.*—Table 1 gives a summary of the bureau's test work for the past year. The total number of tests completed was 200,726, and the fee value \$683,614.51. The corresponding figures for 1929 are 173,512 and \$544,402.33. In 1928 the tests numbered 132,213 with a fee value of \$465,116.82.

TABLE 1.—Numbers of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1930

Kind of instrument or material, class of test, or nature of service rendered	Number of test items for—			Total number of test items	Number of determinations	Fee value
	Public	Government departments and State institutions	Bureau of Standards			
Electrical standards, instruments, and materials.....	784	635	368	1,787	2,762	\$15,955.25
Electric batteries.....		4,210	4	4,214	8,990	24,679.00
Electric lamps and lighting equipment.....	286	3,649	508	4,443	4,536	24,913.02
Length-measuring devices.....	131	142	4	277	2,093	2,712.25
Gages and gage steels.....	2,061	440	213	2,714	11,518	2,557.35
Haemacytometers, sieves, thermal expansion, etc.....	3,382	1,660	127	5,169	18,577	11,443.35
Weights and balances.....	4,969	1,768	1,132	7,869	17,643	7,333.60
Scales.....	28	1,069		1,097	30,558	49,461.50
Timepieces.....	259	33	48	340	4,013	768.50
Volumetric apparatus.....	9,746	4,938	471	15,155	31,197	11,258.45
Hydrometers.....	522	571	38	1,131	2,661	1,359.50
Density determinations, etc.....		10	467	477	562	774.00
Laboratory thermometers.....	2,719	1,105	695	4,519	18,960	10,020.30
Clinical thermometers.....	27,271	73,377		100,648	402,512	13,424.70
Pyrometers, calorimeters, etc.....	176	50	82	308	4,126	3,844.50
Insulating materials.....	52	23	16	91	69	765.00
Fire-resisting materials.....	9	55	4	68	174	7,136.00
Fuels and lubricants.....	246	1,388	209	1,843	9,966	16,636.00
Automotive equipment, etc.....	10	119	47	176	410	4,157.00
Airplane engines.....		46		46	337	67,785.00
Optical instruments and materials.....	603	272	153	1,028	2,862	6,121.70
Carbohydrates.....	20	1,589		1,609	2,508	2,803.00
Radioactive materials.....	1,228	11	1	1,240	1,191	5,567.00
Engineering instruments and appliances.....	118	987	30	1,135	1,288	17,292.00
Aeronautic instruments.....	50	686	16	752	3,540	10,225.50
Aerodynamic tests of models.....	22			22	32	175.00
Physical properties of engineering materials.....	130	2,944	46	3,120	6,345	14,964.60
Sound producing and measuring instruments.....	15	25	1	41	52	815.00
Making of special castings.....		27	147	174	887	2,310.68
Fusible boiler plugs.....		301		301	602	752.50
Metallographic examinations.....		770	198	968	3,710	5,544.09
Miscellaneous metallurgical tests.....		269	347	616	7,059	7,143.75
Pottery and china ware.....		77		77	330	632.50
Glass.....		86	20	106	208	437.00
Refractories and heavy clay products.....		305	56	362	1,334	3,372.00
Cement, concreting materials, lime, etc.....	35	11,959	76	12,070	56,430	156,032.00
Stone and sand-lime brick.....		103	44	153	611	2,096.00
Miscellaneous ceramic materials.....	16	2,085	200	2,311	7,957	15,982.00
Rubber.....	1	1,425	3	1,429	10,613	25,423.50
Textiles.....	23	6,105	805	6,933	15,848	31,078.25
Paper.....	12	1,427	346	1,785	5,689	15,851.00
Leather.....	136	602		738	2,540	3,870.00
Paint, varnish, and bituminous materials.....	2	1,974	33	2,009	15,937	42,585.92
Chemical analysis of metals.....	16	372	187	575	2,361	7,019.75
Chemical tests of miscellaneous materials.....	19	1,162	27	1,208	4,287	11,771.50
Distribution of standard samples.....	7,251	336	5	7,592	79	16,764.00
Total.....	62,348	131,204	7,174	200,726	725,964	683,614.51

<sup>1</sup> Includes fee value of \$5,480.02 for inspecting 2,005,406 incandescent lamps at various factories for other branches of the Government.

<sup>2</sup> Includes fee value of \$47,049 for sampling, testing, and shipping 3,315,116 barrels of Portland cement and 50,200 barrels of masonry cement.

<sup>3</sup> Of these totals 195,124 determinations were for the public, fee value \$72,251.45; 510,507 determinations were for the Government departments and State institutions, fee value \$567,771.27; 20,333 determinations were for the bureau, fee value \$43,591.79. The number of test items, and determinations necessary in connection with the bureau's own work of research and standardization, with the resulting fee values, is not included in these totals.

### SALARIES (\$686,146)

This fund provides for personal services of administration and operation; the establishment, upkeep, and comparison of standards; the development of methods of test, as well as most of the testing; and for the determination of fundamental constants of

importance in physics, chemistry, engineering, and technology not otherwise provided for.

*Standard wave lengths.*—As possibly more suitable as a fundamental unit of length than the wave length of the red radiation from cadmium, the wave lengths of the stronger lines of krypton and of xenon have been compared with neon standards by interferometer methods; the average deviation of an observed wave number from the calculated value is less than 1 part in 20,000,000.

*Special material for line standards.*—The steel mentioned in the annual report for 1929 proved to be unsatisfactory because of inclusions, flaws, and excessive thermal expansion. A systematic search of stainless steels finally located in a 14 per cent chromium and one-half per cent carbon steel a material which appears to be satisfactory from the five standpoints of polish, homogeneity, hardness, thermal expansion (practically same as platinum), and resistance to corrosion.

*Comparisons of length standards.*—The work of intercomparing the bureau's meter bars has been continued, special attention being given to the decimeter intervals of the subdivided meter bars and to a group of 7 decimeter bars, 3 of which belong to the bureau and 4 to cooperating universities. All 7 of these bars were from the same original series issued by the International Bureau of Weights and Measures.

The intercomparison of the bureau's platinum-iridium meters having been completed, the following relations have been determined and will be regarded as official until such time as new certificates may be issued by the International Bureau of Weights and Measures:

$$M\ 27 = 1\ m - 1.40\ \mu + (8.620 + 0.00177\ T) \times 10^{-6} T.$$

as reported by the International Bureau,

$$M\ 21 - M\ 27 = +5.07\ \mu\ \text{at } 23^{\circ}\ \text{C.}$$

$$M\ 12 - M\ 27 = +4.49\ \mu\ \text{at } 23^{\circ}\ \text{C.}$$

$$M\ 4 - M\ 27 = -4.29\ \mu\ \text{at } 23^{\circ}\ \text{C.}$$

as determined at the Bureau of Standards.

Many comparisons of high precision were also made on 4-inch scales and 1-decimeter scales ruled by the interferometric methods.

*Graduation and calibration of circles.*—Three 9-inch circles for first-order Coast and Geodetic Survey theodolites and six 6½-inch circles for second-order theodolites were graduated.

*Methods of length measurement.*—The high precision now being obtained with the bureau's longitudinal comparator made advisable an investigation of computational methods proposed for the determination of corrections to the subintervals of a graduated line standard.

Defects inherent in Guillaume's abbreviated method, which has been used at the bureau for several years, have been pointed out by various writers. The computational methods of Dziobek and Leman are being studied, and although the work is not yet completed, it appears that the average variation of the results of Guillaume's simplified computation from these two results is about 0.02 micron.



*Improvement in accuracy of end standards.*—A set of 11 standards submitted by a manufacturer, ranging by steps of millionths of an inch from a nominal length of 0.100000 to 0.100010 inch, were tested and all found correct within a maximum error of three ten-millionths of an inch in planeness and parallelism of ends, and in length.

*Weights and measures testing.*—Many yard and meter bars, steel tapes, base-line tapes, level rods, sieves, haemacytometers, and other standards, instruments, and devices of this character have been tested. The longitudinal comparator has enabled the bureau to make comparisons and calibrations of length standards with high precision and remarkable rapidity.

*Seconds signals from a pendulum by use of a photo-electric cell.*—Seconds signals from the pendulum of the bureau's Riefler clock, by the use of a photo-electric cell, have been in successful use in three of the laboratories. A new precision clock designed by the chief of the time section, and especially adapted to use with the photo-electric cell, is now being constructed.

*Cooperation with Horological Institute of America.*—Repaired watches, submitted to the institute by individuals as a part of an examination for certification as qualified watch-repair men, have been tested, as heretofore.

*Specifications for stop watches.*—Assistance has been rendered in preparing Federal specifications for stop watches.

*Glass volumetric apparatus and hydrometers.*—The quality of volumetric apparatus submitted for test has remained high, 98 per cent of that submitted having been found qualified for test, and 94 per cent of that tested having passed the test for accuracy of graduation.

*Density of aqua ammonia.*—The necessary material and apparatus for determining the density and thermal expansion of anhydrous ammonia and of various percentages of aqua ammonia have been obtained and the work will be undertaken in the near future.

*Density of chromic-acid solutions.*—Density determinations have been made on several samples of chromic acid.

*Orifice meter tests.*—A group of tests were made in Los Angeles, Calif., on orifices in 16, 8, and 4 inch lines, particular attention being given to large-diameter ratios and high-discharge velocities. The results are very consistent and give additional information on the effect of the expansion factor upon the discharge coefficient.

*Chromium plating, platinum plating, and nichrome for weights.*—Chromium-plated weights given a service test behaved about the same as other electroplated weights of the same type. Old analytical weights plated with platinum have not been found constant, most of them showing a gain. In order to obtain data on the usefulness of nichrome for weights preliminary plans have been made for investigating this material.

*Lacquer for weights.*—Additional tests of insulating lacquers have not developed any which are radically different from those previously investigated. Tests on weights 23 years old show that age has no tendency to change the behavior of shellac lacquer.

*Improvement in constancy of weights.*—The investigation on variability of weights with changes in the humidity of the air has reduced the percentage of variable weights on the market and has



definitely prevented many laboratories from receiving seriously variable weights that would otherwise have been sold to them.

*Maintenance of standard weights.*—About 200 of the standard weights of the mass section of the bureau were recalibrated. This is nearly five times as many as were recalibrated during the preceding year.

*Equipment for testing weights.*—A new high-precision 200-g balance constitutes a valuable addition to the equipment of the section. A high-grade new balance of 50-pound capacity has also been placed in use.

*Ratios of international electrical units to absolute units.*—A considerable number of measurements have been made with the reconstructed Rosa-Dorsey-Miller current balance to determine the value of the international ampere in absolute units, but no final value has been reached. Another type of apparatus for the absolute measurement of current, known as the Pellat current balance, has been designed and partially constructed.

Measurements of inductance preliminary to determining the value of the ohm have been nearly completed on a solenoid wound on a porcelain cylinder, and two additional solenoids have been constructed, one on a pyrex-glass form, the other on a fused-quartz form. These latter solenoids have been made with extreme care and every precaution is being taken in the measurements, with the expectation that the final result will be accurate within 1 part in 100,000.

*Standards of electromotive force.*—Improvements have been made in the standard cell equipment including the design and construction of a new laboratory room especially adapted to the purpose. Additional space has been provided for the increased amount of testing now required, refrigeration is available for holding the temperature of the baths to a constant value in summer, and a new and better oil bath has been constructed for the cells which constitute the primary standard. In moving the primary-standard group from its old location no perceptible change in its value has been introduced, check measurements in the old and new locations agreeing on the average to within four ten-millionths of a volt. Several comparisons have been made with the national laboratories of England, Germany, and Japan. Complete data are not available in all cases, but the results indicate the same relative standing of the units as before.

*Intercomparison of resistance standards.*—Three resistance standards of the new type developed by the bureau were measured at the British and German national laboratories. The results indicate that the unit of electrical resistance as maintained by the three laboratories is in agreement within two or three parts in a hundred thousand.

*Magnetic testing and research.*—An investigation on the standardization of magnetic permeameters was completed. Work was also done on testing with intense fields and on testing with alternating currents at low inductions. In the field of magnetic analysis, experiments were carried out on the relation between magnetic properties and impact strength, and a study of the phenomena associated with the tempering of heat-treated bridge wire was started, using the methods of thermomagnetic analysis.

*Standards of candlepower.*—Four blue glass photometric filters that had already been measured at the Physikalisch-Technische Reichsanstalt and the National Physical Laboratory were measured by three independent methods, and complete reports were submitted to the cooperating laboratories in England, France, and Germany. The glasses have been forwarded to France for measurement at the Laboratoire Central d'Electricité. Carbon-filament standard lamps have also been sent to the national laboratories of England, France, Germany, Union of Socialist Soviet Republics, and Japan for international check measurements.

*Waidner-Burgess standard of light.*—The experimental work in connection with the setting up of this standard has been completed, the technique and procedure having been refined to a point where the operation is mere routine. A thorough study has shown that the standard is reproducible, practical, convenient to operate, and inexpensive. The final result obtained is that an opening 1 square centimeter in area in a black body at the freezing point of platinum emits light equivalent to 58.84 international candles.

*Constant of gravitation.*—This project has been completed and will be given publication in the bureau's Journal of Research within a short time. The mean result obtained is  $6.6670 \times 10^{-8}$  in c. g. s. units.

*Absolute determination of gravity at Washington.*—Preliminary work with brass pendulums has been completed. From the results obtained designs for several pendulums of fused quartz have been prepared. A Shortt clock has been installed for the time measurements necessary.

*Elastic hysteresis research.*—The source of the discrepancy in the values of the elastic hysteresis modulus, when obtained by measuring the deflection of bars under load and by observing the damping of tuning forks, has been finally located. The results by the two methods agree when, in the static method, the load is applied to both prongs of the tuning fork and the point of loading is selected in accordance with the results of a theoretical study.

*Platinum metals.*—A simple and accurate method was developed for the determination of osmium. It is now possible to determine each of the six metals of the platinum group with satisfactory accuracy if they have been separated from each other. Completion of a system of methods of separation is the next phase of the research.

A method was developed for preparing spectrographically pure iridium, but it is not satisfactory, either as to speed or yield, for the preparation of reasonably pure iridium in quantity. The very pure metal is needed for other phases of the work on the properties of the platinum metals.

Some modifications were made in the previously developed method for the purification of osmium. It is possible to prepare any one of the six metals in any desired degree of purity.

*Metallographic technique.*—Many requests have been received for permission to copy the automatic metallographic polishing machine. Using this machine, abrasives and polishing methods suitable for various materials have been studied.

*Pure metals and their alloys.*—A publication was issued on the properties of rhodium and the methods for mechanically working it. Additional data on the physical properties of nickel of the



highest attainable purity and of thorium have been obtained. In cooperation with the alloys-of-iron research committee of Engineering Foundation a critical review of the literature on the preparation and properties of pure iron has been undertaken. The study of the  $A_2$  (magnetic) change in pure iron by means of the  $\beta$ -ray spectrograph has been continued.

*Testing of thermometers.*—About 94 per cent of approximately 100,000 clinical thermometers submitted for test were eligible for certification. Tests are now made in conformity with Commercial Standard CS1-28 except for Government purchases under other specifications.

*Gas thermometry.*—A new manometer was developed for the measurement of gas pressures up to 1.5 meters of mercury with a precision comparable to that attainable in length measurements. Two glass cells, each 6 centimeters internal diameter to minimize capillarity, are connected by a flexible, water-jacketed tube. The distance between the cells is determined by gage blocks. The position of the mercury surface relative to the cell is determined with a precision of about 0.0001 millimeter mercury by means of a special instrument developed and constructed for this work at the bureau. It employs a radiofrequency oscillating circuit which is very sensitive to small changes in electrical capacitance.

*Low-temperature cryostat.*—An improved cryostat, capable of automatically maintaining temperatures as low as  $-150^\circ\text{C.}$ , constant to better than  $0.01^\circ$  was constructed for use in intercomparing laboratory standards and for use in routine testing.

*Application of the glass electrode for pH measurements.*—The degree of acidity, commonly expressed as "pH," is important in many chemical processes, including electroplating. The hydrogen and quinhydrone electrodes and colorimetric indicators previously used in these measurements are not applicable in the presence of oxidizing agents. Results thus far obtained indicate that the "glass electrode" may be applicable to chromic-acid baths and other oxidizing solutions.

*The chloroplatinate-chloroplatinite electrode.*—The electromotive force of this electrode has been found to correspond to a reversible chemical equilibrium. The electromotive force has been measured and the free energy of the reaction determined.

*Thickness of adsorbed films of liquids.*—Measurements of surface tension of soap solutions have shown that there is no evidence for the existence of thick plastic films on the surface of such solutions. An investigation of the viscosity of liquids in very fine capillaries recently completed has shown that there is no rigid adsorbed layer thicker than 0.02 micron on glass or platinum surfaces when covered with liquid, a conclusion of fundamental importance in connection with lubrication.

*The molecular weight of hydrocarbons.*—An improved Victor-Meyer apparatus has been designed and constructed. By making two determinations, one at 1 atmosphere and the other at 0.5 atmosphere, it is possible to determine the molecular weight with an accuracy of about 0.3 of a unit.

*Chemical nature of rubber.*—Very pure rubber hydrocarbon has been prepared in the gel form. By cooling an ethereal solution of

this pure rubber the hydrocarbon is deposited in a crystalline form. Combustion analyses have been completed and apparatus is in course of construction for molecular weight determinations and for obtaining photographs of the crystalline rubber.

*Detergents.*—Information was collected and made available on the preparation and uses of various types of polishes. A circular of information on washing and cleaning materials and their applications was also prepared.

*Analytical reagent chemicals.*—Fifty-seven individual methods for the determination of various impurities in 30 reagent chemicals were studied and in many cases modified or replaced by better methods. As in other years this work formed a substantial part of the preparation of specifications for reagent chemicals by the American Chemical Society.

*Accelerated weathering tests.*—It has been found that the simple cycle of continuous exposure to light from a carbon arc with periodic spraying with water gives valuable information on pigmented coatings, bitumens, etc., but is too drastic for varnishes and other transparent coatings.

*Durability of spar varnish.*—Outdoor exposure starting at two different seasons of the year, laboratory tests, and accelerated weathering tests on a large number of commercial and experimental varnishes showed that while the durability of spar varnish varies greatly, depending on the season exposed, the relative durability of a series of varnishes is quite constant. The accelerated weathering cycle detected the poor varnishes but did not differentiate between good and very good varnishes. The kauri reduction test gave fairly good indications as to durability. Varnishes meeting the Federal specification are above the average in durability, while those made from some of the modern synthetic resins were better than varnishes of the same oil content made from rosin, ester gum, or kauri.

*Softening point of bituminous materials.*—A method based upon a modification of previously used apparatus and procedure for determining the softening point of materials which have no definite melting point has been developed.

*Physical tests for grease.*—The Bulkley consistometer has been found useful in studying the properties of grease. Tests have also been made with a long metal capillary under high pressures showing that the curve for rate of flow of grease, when plotted against inlet pressure, passes through a maximum due to the consistency of the grease being made stiffer under high pressures.

*Standard analytical methods.*—The bureau cooperated with the American Society for Testing Materials in the preparation of methods of analysis for steels, cast irons, and various paint materials, in the preparation of specifications for sampling sheet steel and ferroalloys and tentative specifications for glazier's putty, in exposure tests on the stability of foundry coke, and in investigations on the hiding power of paints and pigments and the tinting strengths of pigments.

*Methods for silvering glass.*—In connection with the preparation of a new circular on silvering glass, considerable work has been done in refining and improving the technique and simplifying the formulas in order to make success in their use more certain and less



dependent upon previous experience. The new circular will give methods for the chemical deposition of silver, copper, platinum, and lead sulphide, and for the production of mirrors by cathode sputtering and by the condensation of metallic vapors on glass.

*Effect of ultra-violet rays on the transparency of special window glasses.*—Exposure to the mercury arc diminishes the ultra-violet transmission of these glasses more than exposure to the sun. It has been found that exposure of these glasses to the sun, after their exposure to the mercury arc, raises their ultra-violet transmission above the minimum value obtained with prolonged exposure to the sun. In 17 out of 20 samples, comprising 6 different makes of special window glasses, the recovery was from 1 to 6 per cent above the minimum value obtained by exposure to the sun alone. This recovery appears to be produced by radiation of wave lengths in the region of 365 millimicrons.

*Construction of instruments and apparatus.*—The bureau's shops constructed many special instruments for the laboratories, including high-grade blown-glass apparatus, and cabinet work such as cases for instruments, besides repairing furniture and woodwork required in the general upkeep of the buildings. Metal specimens for routine tests were machined, and the preparation of standard steel and alloy samples was carried on as before. Apparatus built included the following: Seven resistance standards, air-cooled resistor for current balance, resilience meter, double automatic polishing machine, high-frequency oscillator, wool meter (including optical parts), cathode-ray oscillograph, revolving circuit breaker, flicker photometer, marginal relay, two reflectometers, beat-frequency oscillator, electrostatic voltmeter, hook gage, variable-voltage transformer, expansivity furnace, and an abrasion machine.

*Other projects.*—In addition to the work described in the foregoing paragraphs, some progress has been made on the following: Determination of the regularities in the arc spectrum of titanium and zirconium, Zeeman effects of spectral lines, the "Raman" effect, density changes and refractive index changes produced in glass by various heat treatments, filters for changing the color temperature of incandescent sources to mean sunlight, standards for index of refraction, aberrations of astronomical objectives, actino-electrical and photo-electrical properties of substances, infra-red absorption spectra of selected compounds, resonance radiation excited by higher series lines, thermal expansion of glass at high temperature, measurements of the difference in index of refraction in striae and the surrounding glass, problems of aerial mapping, thermal conductivity of metals, revision of tests of clinical thermometers, construction of special platinum resistance thermometers, correlation of data on thermal properties of methane, precise measurements of pressures from 1 to 100 atmospheres, measurement of diophantine quantities, preparation of equipment for liquefying helium, platinum resistance thermometry at low temperatures, alloys of platinum metals for resistance thermometry at low temperatures, establishment of a practical laboratory scale of temperatures in the range below liquid-air temperatures, standardization of capillary tube vis-

cometers, rotation viscometers, "bleeding" test for greases, reclamation of used oils, preparation of circulars of metallurgical information, particularly on zinc and cadmium.

#### EQUIPMENT (\$88,000)

*Important purchases.*—Several important additions have been made to the bureau's laboratory and plant equipment.

Nine large cylindrical weights of 1,000 pounds each with operating mechanism were purchased for the bureau's 100,000-pound dead-weight testing machine.

A 3-stage electrically driven compressor for pressures up to 500 pounds per square inch, to be used in the liquefaction of helium, was purchased for the low-temperature laboratory.

A new quartz spectrograph was added to the equipment of the spectroscopy section, while an interchangeable glass spectrograph was purchased for the atomic physics section.

Equipment purchased for the radio section included an aircraft radiobeacon receiver, a short-wave aircraft radio-transmitting set, and a large storage battery of 125 cells.

The surface condenser and auxiliary equipment for the new 750-kilowatt turbo-alternator was purchased and installed in the new central power plant. Two storage batteries of 60 cells each, one having a capacity of 240 ampere-hours and equipped with Planté-type plates, and the other with a capacity of 400 ampere-hours with pasted plates, were also purchased for the bureau's plant.

A 750-horsepower electric motor and high-pressure fan were purchased for the automotive power-plants section. These will be installed in one of the existing altitude chambers to be used in connection with dynamometer testing of air-cooled engines.

A spectrophotometer was added to the equipment of the colorimetry section, and a new drying box and auxiliary equipment were purchased for the semicommercial levulose plant.

A 5 by 8 inch double-gearred laboratory rolling mill was bought for the metallurgical division, and a precision bench lathe with 38-inch bed and 8-inch swing has been purchased for the instrument shop.

The equipment of the gage section has been increased by the purchase of 36 sets of internal micrometers with master rings.

In addition, a large amount of smaller equipment has been added to the bureau's power plant, shops, and laboratories.

#### GENERAL EXPENSES (\$64,000)

*Maintenance of mechanical plant.*—The usual maintenance work, such as the replacement of piping, fittings, valves, etc., has been carried on. A number of changes have been made in piping layouts to facilitate connection to the new power plant.

*Electrical construction and repair.*—The usual maintenance work on the electrical installations has been carried on, and a great number of new electrical installations incident to laboratory expansion have been made.

*Plumbing and pipe work.*—In addition to the usual maintenance work on existing pipe work, new extensions to steam, water, gas, air,



and vacuum lines were made incident to the installation of new laboratory equipment. A new water main has been installed to supplement the water supply. Many changes in the pipe work in the north building have been necessary on account of the alterations to be made in that building.

*Library books.*—The number of volumes accessioned was 1,784 (previous year, 1,639), and 101 were canceled, making the total number of accessioned volumes 35,554. Scientific and technical periodicals received number 1,247, as compared with 1,056 last year.

#### IMPROVEMENT AND CARE OF GROUNDS (\$14,400)

Good progress has been made in improvement of the grounds by grading, sodding, and planting of shrubs. The fill at the east end of the industrial building has been completed and will be seeded this fall.

#### TESTING STRUCTURAL MATERIALS (\$268,150)

*City planning and zoning.*—Surveys of city planning and zoning laws and ordinances showed further progress in the use of the bureau's recommendations. A pamphlet on the preparation of zoning ordinances was prepared.

*Construction economics.*—An extensive study was made of the planning and control of public works, and from December on several staff members aided in the department's work of coordinating the activities of Federal, State, and local officials in expediting public-works construction.

*Home financing.*—A preliminary report has been written on the basis of field work regarding the volume of mortgage writing and cost of administration.

*Survey of small-house construction.*—A digest of data obtained through a field survey made last year in 31 cities has been prepared for publication.

*Care and repair of the house.*—A handbook for home owners and those interested in keeping their property in good condition was prepared. It gives simple and specific directions for home repair work and describes tools and materials needed.

*Cooperation with other agencies on building and housing problems.*—Cooperation was continued with Federal and State agencies and with thousands of local governments and private organizations concerned with building and housing. City planning and zoning, building codes, and home-ownership problems were taken up jointly with bodies such as Better Homes in America with its 6,500 local committees and organizations representing architects, engineers, business, civic, and other groups.

*Plumbing investigation.*—An extension of the plumbing investigation carried out in 1921-1923 for the building-code committee of the Department of Commerce has been undertaken in cooperation with the industry to include pipe sizes and design of systems for tall buildings.

Preliminary observations and measurements were made on (1) the capacities of drains and (2) the loads carried by the drains under actual service conditions in five large buildings in New York City



and in two of the larger Government office buildings in Washington. Other data pertaining to the loads on plumbing systems in actual service were obtained. An extensive experimental program is planned for the current year.

*Building codes.*—A survey of the amount and character of combustible contents of typical fire-resistive buildings in Washington, D. C., was made as an aid in classification from the fire-hazard standpoint.

Experimental work to determine the inherent fire hazard and protection required for household heating appliances was nearly completed. This was preceded by a survey of existing conditions in residences and apartments and examination of premises where fires from stoves, furnaces, and their pipes have occurred.

*Cement reference laboratory.*—The cement reference laboratory, a cooperative project of the Bureau of Standards and the American Society for Testing Materials, conducted inspections at 175 laboratories. Apparatus was tested, methods demonstrated, and miscellaneous data collected. This information is proving valuable in outlining further work of the laboratory. Requests for inspection have been received from 194 laboratories, indicating a widespread interest in this work.

*Branch laboratories and inspection of cement.*—The branch laboratories at Northampton, Pa., Denver, Colo., and San Francisco, Calif., all test cement, while the Denver laboratory also tests concreting materials and the San Francisco laboratory makes miscellaneous chemical and physical tests. Cement-inspection service was established at six plants. During the year 1,628,187 barrels were sampled and tested and 1,255,947 barrels shipped to Government projects.

*Diatomaceous silica.*—The effect of adding diatomaceous silica to concrete has been studied. The materials ranged from 7.5 to 34.7 pounds per cubic foot, and most of the material submitted was composed very largely of diatoms. The addition of diatomaceous silica requires the use of more mixing water, the lighter the silica the more water required. Diatomaceous silicas tend to produce a lower strength in concretes of equal flows, but permit a larger flow without the separation of the constituent materials of the concrete.

*Waterproofing compounds.*—Concrete test specimens containing integral waterproofing compounds subjected constantly to a 20 pound water pressure showed in most cases only a slight permeability at the end of one year. After drying in the air of the laboratory for one month permeability generally increased. At the end of a year the majority of these treatments were of little value. About one-third of the specimens were considered to be sufficiently effective for practical use.

*Cast stone.*—Some very unusual characteristics were exhibited by samples of cast stone. The modulus of rupture ranged from 200 to 1,500 pounds per square inch. The compressive strength of the best specimen was 23,000 pounds per square inch, and the strength for all specimens 1,500 pounds per square inch. The maximum 48-hour absorption was 13.5 per cent, and the minimum 2 per cent. The resistance to freezing and thawing ranged from complete failure within 40 cycles to specimens that exhibited no signs of disintegration at 500 cycles.

*Durability of concrete aggregates.*—No one test appears to be suitable for determining the durability of all types of concrete aggregates exposed to freezing and thawing. Petrographic analysis may be used to advantage in determining the merits of the material. The presence of clay in certain forms, such as laminae, seems to cause early disintegration in certain types of rock.

*Concrete masonry units.*—Tests on 50 samples of concrete masonry units gave compressive strengths from 400 to 2,000 pounds per square inch of gross area. There seemed to be no relation between absorption and compressive strength except that usually the sand units had the greatest strength and least absorption while for cinder and haydite blocks the reverse was true.

The weights of sand blocks varied from 125 to 150 pounds per cubic foot, and cinder units from 70 to 100 pounds. Haydite were the lightest, ranging between 70 and 85 pounds per cubic foot.

*Phase study of the system  $\text{CaO-SiO}_2\text{-B}_2\text{O}_3$ .*—A study of a portion of the  $\text{CaO-SiO}_2\text{-B}_2\text{O}_3$  system has shown that the presence of small amounts of  $\text{B}_2\text{O}_3$  in dicalcium silicate lowers the refractive index, and also lowers the temperature of the inversion from the beta to the alpha form.

*Reaction of water on calcium aluminates and calcium aluminate cements.*—The study of the mechanism of the reaction of water on one domestic and seven foreign calcium-aluminate cements, and the ternary compound  $4\text{CaO}.\text{Al}_2\text{O}_3.\text{Fe}_2\text{O}_3$  shows that these cements reacted with water to form a metastable solution in the early periods which approximated the composition of monocalcium aluminate. The boundaries wherein these solutions occur have been determined.

*Clays as admixtures in concrete.*—In cooperation with an engineering firm an investigation of the value of clay admixtures in concrete has been undertaken.

*Survey of common brick.*—In cooperation with the Common Brick Manufacturers Association samples of brick from about 200 plants are being tested to determine their compliance with specifications.

*Test of large concrete cylinders.*—In connection with the design and construction of dams by the Aluminum Co. of America, twenty-three 24 by 48 inch concrete cylinders were fabricated and sent to the bureau for testing. It was found that Poisson's ratio for the concrete was about 0.15 for all stresses within the range from 0 to 1,000 pounds per square inch.

*Tests of the Arlington Memorial Bridge.*—Continuous records of the temperatures of the concrete in one of the main arch spans are being obtained. The average temperature of the arch has varied between 28° and 80° F. Measurements of the deformations and deflections of the arch barrel caused by temperature changes, both before and after the construction of the walls and roadway, were made to determine the effect of the restraint of the superstructure on the deformations of the arch.

*Transmission of water through brick masonry.*—The durability of bond between brick and mortar may be improved by finding and using mortars which, under any conditions, undergo relatively small volume changes. It is believed that there are several ways in which this may be accomplished without any material increase in labor or building cost.



*Properties of sand-lime brick.*—In determining weathering ability, partial immersion as well as total immersion absorption data have been obtained together with the bulk volume and density of the bricks. Freezing and thawing cycles on these bricks are now being made to find whether there is any correlation between absorptive properties and resistance to freezing and thawing.

*Manufacture of gypsum products.*—Properties of gypsum fiber concrete: Volumetric changes of gypsum fiber concrete made from five different lots of calcined gypsum are being studied. Setting expansions range from 0.06 to 0.40 per cent. Within the temperature range of 25° to 45° C. the thermal coefficient of expansion of the neat gypsum specimens is about  $160 \times 10^{-7}$  and that of the fiber concrete containing 12.5 per cent wood chips about  $130 \times 10^{-7}$ .

*Lime investigation.*—(a) Soundness of hydrated lime: Steaming a paste of hydrated lime in an autoclave at 120 pounds pressure has proven most satisfactory to determine the soundness of hydrated lime. It is hoped that the method may also be made applicable for testing the soundness of pulverized quicklime.

(b) Particle-size distribution of hydrated lime: The particle-size distribution of hydrated lime is being studied by determining the rate of sedimentation of lime in anhydrous normal butyl alcohol.

(c) Specifications for chemical lime: Recommended specifications for quicklime and hydrated lime for use in soap making have been published.

*Elastic pointing materials.*—A special apparatus which has materially simplified the testing process has been designed and built to determine the effectiveness of these materials in masonry joints when subjected to tensile stresses.

*Slate.*—Samples of roofing slate were secured from old buildings where they had been exposed under service conditions for periods ranging from 12 to more than 100 years. This has afforded considerable information on the nature and causes of slate weathering. Some deposits of slate in this country seem to be very resistant to destructive weathering agents, while others may not be good for more than 25 years of service.

*Blistering of vitreous enamels on gray cast iron.*—This work in cooperation with the American Ceramic Society shows that "blistering" irons possess a much narrower range of temperatures within which the enamel can be burned without blister formation than do nonblistering irons. The range of suitable firing temperatures for a given iron corresponds with a decrease in the rate, or a cessation of the oxidation of carbon from the surface of the iron. Rapid oxidation of carbon from the surface is believed to reduce the presence of "temper carbon," a very finely divided carbon formed immediately in the breakdown of cementite and previous to agglomeration to the coarser "graphite carbon." In general, the removal of the surface layer from a "blistering" iron renders it "non-blistering" in its behavior when enameled.

*Chemical testing and methods of analysis.*—Samples of structural materials were tested for various branches of the Government. These included Portland cement, cast irons, steels, alloy steels, ferro-alloys, brasses, bronzes, bearing metals, boiler plugs, Monel metal, and light aluminum alloys. Several improved and more rapid test methods were developed.



## TESTING MACHINES (\$41,000)

*Hardness testing of metals.*—During the past two years, a large number of steel specimens, having high Brinell numbers, have been tested. The results have been used in the derivation of formulas for the relation between the Rockwell and the Brinell numbers. The new formulas do not differ greatly from earlier formulas published by the Bureau of Standards but give the metallurgical industry more reliable methods of obtaining the Rockwell number from the Brinell number or vice versa. Recommendations have likewise been prepared covering the use of the Brinell machine, which should secure greater uniformity in test results from different observers.

*Electrically welded steel tubing.*—The physical properties of tubing made from sheet steel containing from 0.08 to 0.25 per cent carbon, in which the longitudinal seam was welded under pressure by the electrical-resistance method were determined. Seven different tests were applied, which showed that the properties of the base metal (the metal not affected by the welding operation) can be used in determining the working stresses for different structural uses of tubing made by this process.

*Flat plates under edge compression.*—In the pontoons or floats of seaplanes and in the outer covering of airplane fuselages flat plates are subjected to compressive forces in the plane of the plate. In order to determine the loads such plates can carry, an investigation was conducted in cooperation with the Aeronautics Branch. Tests were made on four different materials—nickel, duralumin, stainless iron, and Monel metal, having thicknesses up to 0.095 inch, a length of 24 inches (direction of load), and widths up to 24 inches. It was found that the plates could be subjected to an increase of load after they had begun to buckle and that especially in the thinner and wider specimens it was possible for the plate to carry many times its theoretical buckling load under uniform thrust without permanent deformation.

*Fixation of struts.*—The strength of tubular steel struts as used in airplane fuselages, loaded in compression and with their ends restrained, is being determined in cooperation with the National Advisory Committee for Aeronautics and the Navy Department. Various conditions of end support, varying from no restraint to infinite restraint are being used, and it is expected that the results of this investigation will enable designers to reduce the weight of aircraft structures with safety.

*Welded structures.*—In cooperation with the structural steel welding committee of the American Bureau of Welding, tensile tests have been made of 125 large welded joints, as an aid in determining safe working stresses when designing welded structures.

*Torsional properties of tubing.*—An investigation of the torsional properties of tubes for aircraft structures has been undertaken in cooperation with the Bureau of Aeronautics, Navy Department. The first tests are being made on standard sizes of chrome-molybdenum steel tubing up to 2 inches in diameter and up to 0.065 inch thick. These specimens fail by buckling after permanent deformation of the material has begun. These results will enable designers to estimate closely the torsional strength of tubular members of aircraft.

*Specifications for empty shipping containers.*—With the cooperation of the Forest Products Laboratory and the industry, tentative specifications have been prepared for solid-fiber boxes, corrugated-fiber boxes, nailed and lock-corner wooden boxes, plywood boxes, and wire-bound boxes. Specifications for sheet-steel drums and for cylinders for compressed gases are in preparation.

#### INVESTIGATION OF FIRE-RESISTING PROPERTIES (\$30,000)

*Furnace for fire tests of walls and partitions.*—A new gas-fired furnace for conducting fire tests of wall and partition constructions was completed which accommodates specimens 11 feet high and 16 feet wide and in which loads up to 350,000 pounds can be applied.

*Tests of fire-detecting systems.*—Tests were made of five automatic fire-detecting systems for the Steamboat Inspection Service to determine their acceptability under the law requiring their installation on passenger vessels.

*Fire tests of roofing materials.*—Data on fire tests of roofing materials in common use were prepared for publication. These included new materials, and similar materials from roofs 5 to 30 years old, as well as new and weathered roofings covered or impregnated with fire-retardant compounds.

*Spontaneous heating and ignition of materials.*—Determinations of ignition temperature and susceptibility to spontaneous heating of various materials have been made at the request of other Government departments, using available equipment and methods. Additional fundamental test methods for this work are being developed.

Research on the susceptibility to spontaneous heating and ignition of jute is being conducted in cooperation with the Bureau of Chemistry and Soils of the Department of Agriculture and a committee of the Marine Underwriters. The results indicate that jute presents no greater hazard from this standpoint than other materials that are generally regarded as presenting at the most a low hazard.

*Other active research projects.*—Plans for temporary equipment for fire tests of welded steel floor constructions, to be conducted in cooperation with the American Institute of Steel Construction, were completed. Fire tests were made of columns protected by precast and poured gypsum. Work was continued on the report giving results of compression tests of steel and cast iron at high temperatures. Fire, impact, and loading tests were made of insulated safes to obtain data for revision of Federal specifications. Tests were made to determine the effectiveness of fire-retardant surface treatments for wood scaffolding.

Technical assistance was given in connection with tests of sprinkler systems in airplane hangars, conducted by the Aeronautics Branch, and in the formation of an organization of Government officials concerned with fire prevention.

#### INVESTIGATION OF PUBLIC-UTILITY STANDARDS (\$107,290)

*Measurement of high voltages and large currents.*—The large absolute high-voltage electrometer was operated in some preliminary trials at 90,000 volts and showed the expected sensitivity. Modifi-



cations have been made to reduce air-current disturbances. A special microscope has been constructed for determining the location of the attracted disk relative to the guard ring.

A standard current transformer and accessory apparatus, which have been completed, raise the possible range of testing from 2,500 to 6,000 amperes.

*Electrical codes.*—Assistance was given in completing the revision of the Wisconsin State Electrical Code. The preparation of a pictorial edition of the National Electrical Safety Code was continued. In cooperation with a national committee, specifications for testing line insulators of more than 750 volts were completed. Assistance was rendered the International Electrotechnical Commission on regulations for overhead transmission lines and the National Board of Fire Underwriters in revising the National Electrical Code.

*Protection against lightning.*—Miscellaneous Publication No. 95, entitled "Protection of Electrical Circuits and Equipment against Lightning," was issued. Assistance was given the National Fire Protection Association in the preparation of a report dealing with oil tanks, and an investigation was carried on in the oil fields of California, Oklahoma, and Kansas.

*Government telephone service.*—The bureau's work on telephone service has been directed almost entirely to the planning of efficient and economical service for Government offices in Washington and elsewhere, and to the defense of damage suits involving very large claims for telephone equipment used here and abroad during the war period.

The first unit of a group of dial private-branch telephone exchanges planned to serve in a properly coordinated and thoroughly modern manner the executive departments and establishments in Washington was put into service May 31. For the new Commerce Building, which will house all of that department's activities except the Bureau of Standards, a consolidated, combination dial and manual, private-branch exchange has been designed.

Detailed studies were carried out for the Budget Bureau on the telephone service for Federal agencies in cities outside of Washington, and recommendations were made for Asheville, Chicago, Fargo, Kansas City, San Diego, San Francisco, and Springfield, Ill.

*Underground corrosion.*—About 3,000 specimens of pipe materials have been removed from 70 locations. Their condition and that of the soil in which they were buried are being determined. This is part of a 12-year project now two-thirds completed.

Field tests of 50 protective coatings in 29 soils have been started with the cooperation of coating manufacturers, the American Gas Association, and the American Petroleum Institute, who will bear about two-thirds of the expense of the investigation.

*Hotel ranges.*—The efficiency of ovens and cooking tops of hotel gas ranges was measured and a limited amount of work was done on domestic electric ranges to assist Government institutions, such as hospitals, barracks, etc., in the selection of such equipment.

*Corrosion of materials for gas-oven linings.*—A large number of materials have been tested by an improved method. The corroded materials have been submitted to a committee of the American Gas Association, which contributed to the research as an aid in preparing specifications.



*Domestic range burners.*—An investigation of the optimum design of domestic gas-range burners for using carbureted water gas was conducted to find how design factors differ when using water gas as compared with propane and butane previously studied.

*Use of propane in the Lighthouse Service.*—It has been found that propane burners could be substituted for the kerosene burners now used for the larger lights with a simplification of equipment requiring less attention from the operator, and with the same efficiency in terms of candlepower-hours per thousand British thermal units. The greater cost of propane at the present time probably makes its substitution for kerosene inadvisable except possibly for unattended stationary lights.

#### TESTING MISCELLANEOUS MATERIALS (\$46,400)

A great variety of tests were made for Government departments on paints, varnishes, roofing and waterproofing materials, rubber goods, packings, inks, typewriter ribbons, carbon paper, textiles, boiler waters and compounds, detergents, chemicals, gold alloys, etc. Miscellaneous materials were tested to determine their fire hazard to guide the Steamboat Inspection Service in making rulings on the transportation of commodities on passenger vessels.

#### RADIO RESEARCH (\$85,700)

*Primary frequency standard.*—A primary frequency standard with an error of one part in several millions, consisting of four special piezooscillators of great accuracy, has been in operation for several months. Currents are furnished by this standard at 100,000, 10,000, 1,000, 100, and 10 cycles per second, and seconds impulses are given. These accurately known frequencies can be made available for measurement purposes in most of the bureau's buildings. The frequencies of the four piezooscillators are found to increase at the rate of about one part in a million per month.

*Secondary frequency standards.*—Some of the causes of erratic behavior of temperature-controlled piezooscillators constructed by the bureau have been eradicated by improvements in design. Two of the best piezooscillators maintain their frequencies from day to day within  $\pm 1$  part in a million. The frequencies of this group of piezooscillators have been found to increase about one or two parts in a million per month.

*Standard frequency dissemination.*—Regularly scheduled transmissions of eight frequencies per month were sent out for the use of all those interested in accurate frequency calibration. The accuracy of these transmissions is better than 0.01 per cent.

*Intercomparison of frequency standards of various laboratories.*—The frequency standards of several foreign countries were intercompared by carrying a piezooscillator to the different laboratories and by measurements on a quartz light resonator circulated by Japan. The latter measurements showed the national standards of four nations to be in agreement within 0.002 per cent.

*Measurement of radio field intensity.*—Field intensity measurements made at frequencies from 550 to 5,400 kilocycles per second over distances up to 3,200 meters over fresh water show that 15 per

cent of the signal is absorbed at 1,500 kilocycles and about 50 per cent is absorbed at 5,400 kilocycles. Measurements of transmissions from broadcasting and Government stations at distances up to 270 kilometers show that the absorption at a distance of 270 kilometers is 99 per cent for a 760-kilocycle transmission and 90 per cent for a 338-kilocycle transmission.

*Variations of radio wave intensity and direction.*—Measurements with an automatic fading recorder at the Kensington field station show that magnetic storms do not affect the received intensity but increase atmospheric absorption. The eclipse of April 28, 1930, did not affect the records.

*Height of the Kennelly-Heavyside layer.*—Oscillographic records made on pulse signals sent by NKF on 4,045 kilocycles and 8,650 kilocycles show the virtual height of the Kennelly-Heavyside layer to be from 225 to 250 kilometers on 4,045 kilocycles and about 290 kilometers on 8,650 kilocycles. A 100-kilometer layer was also observed on the lower frequency. The height of the layer changes during the day and is affected by magnetic storms.

*Studies of piezo-electricity.*—The modes of vibration of crystalline quartz plates of various cuts have been studied by observing the patterns formed by lycopodium powder on the surfaces of the plates. The air currents emanating from the periphery of a vibrating circular plate have been utilized to determine the angle of vibration of the plate. The experimental work has been accompanied by a theoretical study of the problem of free vibrations of an elastic solid.

*Radio-frequency power factor of mica.*—Power-factor measurements between 100 and 1,000 kilocycles per second were made on 34 samples of domestic and foreign mica for the Bureau of Mines for use in a report to the War Department.

#### COLOR STANDARDIZATION (\$15,800)

*Filters for the reproduction of sunlight and daylight and the determination of color temperature.*—A series of filters reproducible from chemical specification has been developed for use in photographic sensitometry, colorimetry, and photometry. One has been recommended for adoption as a standard of artificial sunlight by the Seventh International Congress of Photography. Others are being considered for adoption as standards by the subcommittee on colorimetry of the International Commission on Illumination.

*Theory of reduction of mixture data in colorimetry.*—A paper on the mathematical treatment of physical properties which determine the colors of reflective and transmissive materials and on the data which give the properties of the average normal eye has been published.

*Standardization of Lovibond glasses.*—Two hundred and twenty-five Lovibond red glasses submitted by users have been compared with the bureau's standard glasses. In addition, 36 glasses submitted by the makers, Tintometer (Ltd.), of England, and 19 belonging to the American Oil Chemists' Society were compared with the standards.

*New color comparator for incandescent lamps.*—The experimental conditions affecting accuracy of comparison of two colors have been



studied, and a comparator designed for incandescent lamps has been constructed. It has been found that the precision is about double that obtainable with the comparator previously used.

*Miscellaneous.*—Lack of space prevents more than mention of the following investigations on which work has been done during the year: Analysis of color stimuli in terms of dominant wave length and purity, selection of a standard neutral stimulus for colorimetric purposes, color specifications for railway and traffic signals, diffuse reflection and its measurement, and standard data on reflection of various materials.

#### INVESTIGATION OF CLAY PRODUCTS (\$49,000)

*Crazing of semiporcelain dinner ware.*—The effect of composition and physical structure on changes in volume, as produced by reactions of water-permeable bodies with moisture, as well as the nature of the reaction itself, are being studied with the autoclave. It appears that bodies of more than 2 per cent water absorption will undergo a sufficient change in volume when subjected to moisture to rupture or craze a glaze coating. Feldspar may undergo greater volume changes than clay matter and a temperature of at least 240° C. is required to remove the moisture causing this change in volume and to complete the accompanying volume contraction.

*Cutlery marking of chinaware.*—Permanent marking of chinaware by cutlery appears to be due to the formation of an extremely thin layer of lead sulphate on the surface of the glaze during the manufacture of the ware. One manufacturer was able to produce ware no longer susceptible to this cutlery marking by substituting an electrically heated muffle for the firing of his decorated ware.

*Study of feldspar.*—A tentative commercial standard classification for feldspar has been established. The suggested specification is entirely technical in nature and is based on an investigation of 19 commercial feldspars which has been carried on for several years.

*Study of fire clays.*—Data obtained on 26 representative fire clays show that their thermal expansions after firing at 1,400° C. may be greater or less than after firing at 1,155° C., depending on their composition. The moduli of elasticity and rupture of the clays are generally greater after firing at 1,400° C. than after firing at 1,155° C. The percentage increase is greater in highly siliceous clays than in aluminous clays. The plastic deflections of the clays are also less in the siliceous type of clays than in the aluminous.

*Problems relating to saggers.*—It has been found that the life of saggers made from individual bodies is directly related to small changes in porosity, but because of the importance of other properties, which have also been determined, the porosity of a series of different bodies apparently does not bear an important relation to their life when subjected to thermal shock.

*Effect of variations in composition on vitreous enamels.*—Two vitreous enamels having identical calculated melted compositions, but differing in their raw batch mixtures, were prepared. The cone formation temperatures of the two resulting enamels differed by approximately 40° C. Additional heat treatment at the temperature of preparation (1,250° C.), was given and records obtained of the cone



deformation temperatures and indices of refraction. These indicate that the initial difference in properties is due to a more stable condition than that of mere arrested reaction.

*Resistance of metals to the abrasive action of plastic clay.*—Comparative wear values of 12 metals and alloys have been studied with the following results, the resistance of a chrome-nickel-tungsten composition being used as unity: Carbon-cobalt-chromium, 2.3; average for several cast irons, 30.9; carbon-chromium-nickel steel, 39.1; electrolytic copper, 161; and manganese-zinc bronze, 276.8.

Casehardened metals are not suitable for continuous abrasive resistance. As soon as the outer layer is worn away the successive layers become less wear resisting.

*Hollow-ware dies.*—This investigation has shown that within reasonable limits both "core" and "die" length have a more marked effect on power consumption than taper without a proportional improvement in the column structure. Hollow-ware dies that are too short produce columns with serious defects. Taper affects the column structure more than it does power consumption and rarely should be less than  $3^{\circ}$  for both cores and die.

Compressible lubricants such as steam and air are far more efficient, easier to control, and less liable to damage the product than liquids, such as water and oil.

*Properties of architectural terra cotta.*—In cooperation with the National Terra Cotta Society, about 190 buildings containing terra cotta were inspected to determine the serviceability of this ware. Laboratory research is being conducted to improve the structure of this material and to develop better methods of manufacture and setting.

Ceramic bodies (except mixtures containing blast-furnace slag), with high-moisture absorptions, developed considerable expansion. Bodies with low absorptions composed of pure clay and feldspar developed practically no moisture expansion, while those composed of clay, feldspar, and more than 20 per cent silica developed considerable moisture expansion. By adding magnesite the resistance of a ceramic body to moisture expansion was improved. Additions of whiting, iron oxide, and titanium oxide were not as beneficial as magnesite.

It was found that crazing caused by moisture expansion of bodies can usually be prevented by proper manufacturing control.

*Columbus laboratory.*—As the result of experimental work on 118 glazes and glasses, it is now possible to approximate by calculation values of tensile strength, Young's modulus of elasticity, and mean linear coefficient of expansion of a glaze in the temperature range from  $25^{\circ}$  C. to the lower limit of the critical range. The investigation of English and domestic china clays and kaolins is nearing completion. The separation and study of colloidal material has been applied to the investigation of representative alluvial and glacial clays, the data indicating that slaking time, tempering water, drying shrinkage, and "green" modulus of rupture tend to increase with increase in the quantity of colloidal matter. A new method has been developed for studying the relative resistance of refractories to slag attack in boiler settings.

## STANDARDIZING MECHANICAL APPLIANCES (\$29,300)

*Testing of engineering instruments.*—The number of calibrations of water-current meters and other engineering instruments now exceeds 1,000 per year. Experimental work was done in cooperation with the United States Geological Survey in the development of new standard suspension arrangements for water-current meters.

*Investigation of propeller fans.*—In cooperation with a manufacturer the performance of 2-blade propeller fans has been measured for a wide range of pitch-diameter ratios and the results of the measurements prepared for publication in the Journal of Research.

*Fire-extinguishing appliances.*—The testing and investigation of fire-extinguishing appliances, principally for the Steamboat Inspection Service, has been further extended to include additional devices and new types of equipment. The volume of this work has more than doubled in the past year.

*Elevator safety interlocks.*—Additional commercial interlocking devices have been tested, and the data made available to certain regulatory bodies, as, for example, the Federal Government, certain State governments, and casualty insurance companies. These performance tests have recently been adopted, substantially in the form originally developed, as a part of the American Standard Code for Elevators.

*Automatic postal machines.*—Cooperation has continued with the Post Office Department in the technical study and testing of automatic postage-vending and postage-metering machines from the standpoint of mechanical design, accuracy, and reliability for use by the Government.

*Numbering machines.*—Numbering machines of the lever type have been tested for compliance with Federal specifications. Performance specifications are being developed for numbering machines of other types.

*Thermostatic radiator traps.*—The new Government construction program requires a great many thermostatic radiator return line traps, and an unusually large number of tests of these traps have been made during the year.

## INVESTIGATION OF OPTICAL GLASS (\$27,300)

*Production of optical glass.*—Thirty-one pots embracing six different kinds of optical glass were made in attempts to improve melting procedures and to obtain consistently satisfactory quantities of good glass.

Blanks numbering 12,552 and weighing approximately 2,670 pounds were molded and annealed, the majority being used by the Navy Department.

*Viscosity of glass.*—Four hundred and six viscosity determinations have been made on five kinds of optical glass. The most probable values, as shown by graphical analyses of data, are as follows:



Kind of glass	Viscosity (poises) at—				
	1,000° C.	1,100° C.	1,200° C.	1,300° C.	1,400° C.
Barium flint.....	8,510	1,514	403	149	74
Light barium crown.....	6,840	858	234	94	60
Borosilicate crown.....	3,390	667	221	120	100
Medium flint.....	2,140	672	253	110	50
Dense flint.....	2,100	490	190	93	54

*Physical properties of glass as affected by thermal treatment (including annealing).—*Tentative values for the increases in refractivity and density of dense barium crown glass have been found to be respectively 0.000057 and 0.00044 per degree centigrade decrease in the effective annealing temperature. This temperature is determined by the character of the annealing and is essentially that temperature at which the glass is in physiochemical equilibrium; that is, continued annealing at this temperature causes the glass to show no further increase or decrease in either density or refractivity.

*Gases dissolved in glass.*—More satisfactory methods have been developed for determining the gases in glass which can be removed at high temperature by evacuation. Since these gases probably have appreciable effects on the properties of the glass and may be the undetermined cause of serious difficulty in the working, the development is of considerable importance.

*Relations between chemical composition, density, and index of refraction of glasses.*—Data obtained from the index of refraction, density, and composition of 40 glasses of the soda-lime-silica series lead to the conclusion that the index of refraction ( $N$ ) and density ( $D$ ) of these glasses can be computed from the following:

$$N = a + b + c$$

$$D = a' + b' + c'$$

$$a = 0.042712(A)^{0.79487} - 0.2$$

$$b = 0.0153 B - 0.00837$$

$$c = 0.017219 C - 0.00103$$

$$a' = 0.07977 A (86.5 - A)^{0.42107} + 2.203 A$$

$$b' = 2.0150 (B - 0.5)^{1.065}$$

$$c' = 0.03415 C \left( \frac{A}{B} \right) - 0.04743$$

in which  $A$ ,  $B$ , and  $C$  are the percentages of silica, soda, and lime in the glass.

The composition of any glass of this series can be determined from its index of refraction and density.

*Weathering of sheet glass in storage.*—A study of this problem has been undertaken to determine, if possible, the conditions necessary to prevent the fogging or surface deterioration of window glass during storage and the consequent loss to manufacturers of many thousands of dollars annually.

#### INVESTIGATION OF TEXTILES, ETC. (\$53,900)

*Silk weighting.*—In cooperation with the Silk Association of America, National Retail Dry Goods Association, National Better Business Bureau, the American Home Economics Association, and



other national bodies, technical studies have been made on the effect of tin weighting on the properties of silk. It was found that not only the amount of weighting, but also the method of applying it, the construction of the fabric, and other factors have an important influence on serviceability. The effect of diffuse light on weighted silks was studied. A standard method for determining the amount of weighting on silk was developed.

*Cotton fabric for parachutes.*—In cooperation with the National Advisory Committee for Aeronautics, improvements were made in cotton fabric for parachutes, which increase the resistance to tear. At the present time, at least two commercial firms are producing fabric suitable for parachutes.

*Coarse fabrics (bagging, etc.).*—In studying the requirements of specific uses in the coarse-fabric field, a systematic study of the relationship between the properties and the twist, yarn number, and construction was made. This investigation required the making of 320 fabrics in the bureau's cotton mill.

*Textile test methods.*—A simple method has been devised for specifying the slipperiness or smoothness of a fabric by measurement of the coefficient of friction between two pieces of the material. A "flexometer" for measuring the energy required to fold the fabric and the energy which is recovered when the sample is allowed to unfold has been built. This gives data on the tendency to wrinkle. It is believed that the flexometer can also be applied to the evaluation of draping quality. An apparatus for rapidly measuring the thermal transmission of fabrics has been built.

*Permanence of papers.*—The testing of representative current commercial writing and printing papers in reference to their probable stability has been practically completed. Progress was made in the preparation of similar types of papers in the bureau's paper mill. These papers will have a definitely known history, and the chemicals and mechanical processes used in their preparation are being varied to measure their effect on paper stability. With a fund granted by the Carnegie Foundation, extensive surveys of library storage conditions and a study of their effects on papers are being made. The information so far gained shows that the degree of purity of papers and their strength are the important factors in their permanence.

*Government papers.*—Additional information was published on the currency-paper study. Various treatments for protection of the paper money against surface wear, which is now the main limiting factor in its life, were investigated. In the cooperative investigation with the Bureau of Engraving and Printing on postage stamps, the type of paper used was found to be the most important factor affecting adhesion of stamps. Through experimental studies, a thinner and more flexible paper was developed. Since the adoption of this type of paper, complaints respecting nonadherence of stamps have decreased to a satisfactory minimum.

*Paper testing methods.*—A report was published on the bursting-strength test, including a discussion of the alleged variables in this test, and precautions were suggested for minimizing the effect of the more significant variables. An additional publication on the standard type of folding tester was issued. Progress was made in

obtaining information on the application of hygrometry to the special conditions of laboratory testing. The cooperative work with the Technical Association of the Pulp and Paper Industry on the development of official association paper-testing methods resulted in the completion of a method for unimpregnated roofing felt, and revision of the methods for paraffin, starch, and fiber composition.

*Miscellaneous.*—Additional work under this fund has included an investigation of substitutes for chromium in dyes (for the War Department), the development of a white stainless mineral oil for knitting machines, studies of several new materials, including New Zealand flax, for paper making, and the establishment of standards of quality for several paper products.

#### SUGAR STANDARDIZATION (\$75,000)

*The structure of the sugars.*—In the bureau's study of the molecular structure of sugar a number of new compounds and methods have been found, among which were (1) a method for separating methyl glycosides which yielded two crystalline methyl gulosides, and (2) a method for deacetylation by means of a small quantity of barium methylate which gave monoacetylglucosido-mannose, a representative of a new type of sugar derivatives. The general problem of a possible relation between optical rotation and atomic dimension was attacked, and what is known as the fluorating process for sugars was studied. Four new crystalline compounds of levulose were prepared.

*Crystallographic studies of the sugars.*—The identification of crystals and the determination of their crystallographic properties has become an indispensable aid to the advancement of knowledge in the carbohydrate field. The bureau's facilities for this work have been extended, including microphotographic work and the actual growing of perfect crystals under controlled conditions. A study of crystalline turanose, a little-understood rare sugar, has been completed.

*Standardization of sugar products.*—The problem of suitable specifications and standards for commercial sugars has long been one of the outstanding problems in the sugar industry. Numerous representative samples of white granulated sucrose were carefully studied by means of spectrophotometric analysis, and existing knowledge of the small but all-important amount of color remaining in these so-called white products was materially extended thereby. It is expected that these data will be of assistance in the classification of commercial sugars according to color. An important by-product of this work was the simplification and improvement of some methods used in sugar colorimetry.

*Hard refined levulose production.*—Portions of the bureau's plant for the semicommercial production of levulose were placed in operation and studies made of the functioning of various steps in the process. Several new pieces of equipment were developed. Constant improvement has been made in a system of analyses of levulose products, and the densities, rotatory powers, and refractive indices of pure levulose solutions have been determined. Two new crystalline difructose anhydrides have been discovered. Approximately 50 tons of artichokes were extracted and the juice concentrated to furnish a continuous supply of material for factory experimentation.



*Miscellaneous.*—In addition to the items described above, progress has been made on the following investigations: The rotation and rotation dispersion of rare sugars for certain wave lengths of light; spectrophotometric measurement of the color of soft sugar; preparation of pure sugars; a standard sugar color, its absorption spectrum, luminosity, and classification; an optical method for the identification of various sugars; the lime precipitation of levulose and its crystallization from aqueous solution; preparation of ribose; identification and properties of unknown constituents of hydrolyzed inulin; the polysaccharides of the Jerusalem-artichoke and similar plants; investigation of the relation of optical rotation to atomic dimension; and the application of the fluorating process to sugars.

#### GAGE STANDARDIZATION (\$40,000)

*Certification of master gages.*—The measurement and certification of the accuracy of the dimensions of master gages has constituted a large part of the work, and, as in other recent years, the master gages of the American Petroleum Institute have constituted an important item. The measurement of the grand and regional masters of American Petroleum Institute rotary tool joint gages has been practically completed. The principal manufacturers of sucker rods are now supplied with approved gages. Increased tolerances (not, however, inconsistent with approved gaging practice) are now being used on these gages. Master gages were also submitted by many automobile manufacturers, and there was a 70 per cent increase in the number of precision gage blocks tested.

*New equipment.*—A comparator for long gage blocks and end standards up to 60 inches in length and a lead-testing device were designed and constructed in the bureau's shop. An improved lead-testing device for large thread plugs and rings was made, and a device for measuring angular displacements or spacing, to an accuracy of about 5 minutes of arc, was purchased.

*Method of gaging fish nets.*—At the request of the Bureau of Fisheries an investigation has been started of methods of gaging the mesh of gill netting. Preliminary results show that "as fished" condition rather than the factory condition should apply when making measurements.

*Interchangeable ground-glass joints.*—Nine sizes of joints have been adopted as commercial standards for chemical glass apparatus. All have a taper of 1 in 10 on diameter. Steps have been taken to secure gages of the required accuracy for use as masters.

#### INVESTIGATION OF MINE SCALES AND CARS (\$13,400)

*Tests of mine scales.*—The mine-scale testing equipment was operated in the eastern coal fields. Tests were made of 185 scales used for weighing coal or clay at the mine. Sixty-three scales, or 34.1 per cent, were within the tolerance, while 122, or 65.9 per cent, were found to be incorrect. Installation practices and operating conditions at mines are not favorable to maintenance of weighing machinery within current tolerances.



*Protective coatings for heavy weights.*—Research was begun on adequate corrosion protective coatings for industrial test weights of large denomination. The condition of a great number of weights treated with a variety of recommended protective coatings and subjected to practical conditions of use will be recorded from time to time.

#### METALLURGICAL RESEARCH (\$51,000)

*Heat-treated bridge wire.*—The strength necessary in wire for the cables of suspension bridges may be developed by cold working or by heat treatment. Wire of the former class is, however, used exclusively for this purpose, since attempts to use heat-treated wire have been unsuccessful. Various tests, including thermomagnetic analyses, endurance, and other mechanical tests have been made on rejected heat-treated wire. The work will be continued with special attention to the effect of surface conditions arising in the zinc-coating operation upon the stability of the wire under various conditions of stress.

*High-speed tool steel and the machineability of steel.*—A report has been issued on the characteristic behavior of tools of high-speed steel containing various addition elements, of which cobalt is the only one which appears to be beneficial in its effect. A report was also published on the method for studying the behavior of tools when used for finishing cuts. A similar report on the behavior of sintered tungsten carbide lathe-cutting tools has been published.

*Rail steel.*—The tensile properties of rail steel at temperatures ranging from normal room temperature to one somewhat below the rolling temperature of the rails have been studied, and the probable relationship determined between the low ductility observed at the elevated temperature—"secondary brittleness"—and the development of transverse fissures in the rails later in service.

Further work is in progress on rail steel of various compositions and heat treatment in the endeavor to establish the cause of the phenomenon of "secondary brittleness."

*Fusible boiler plugs.*—Changes have been recommended in the specifications for fusible-tin boiler plugs, one, which has received the approval of the Steamboat Inspection Service, being that maximum impurities in the tin filling of 0.7 per cent will be allowed instead of 0.3 per cent as heretofore.

*Properties and new uses for bismuth.*—In cooperation with one of the large producers a study has been made of bismuth and some of its alloys. This little-used metal possesses some interesting properties which should make it of value industrially.

*Foundry materials and methods.*—Cooperation with the Steel Castings Research Bureau in the study of steel castings has been continued. The problem of "liquid shrinkage" of cast metals (in cooperation with the American Foundrymen's Association) has included a study of methods for determining the volume changes undergone by metals cooling from the liquid state to room temperature. Data obtained permit construction of the complete specific volume-temperature curve from room temperature to a temperature considerably above the melting point of the metal. These tests are being applied in a practical manner to a variety of cast irons.

The test for determining the ability of molten metal to fill a mold completely has been modified and greatly improved.

*Metals of the platinum group.*—The study of the refractories for use in melting metals of the platinum group has been completed, while that on the properties and mechanical working of the rhodium-platinum alloys is nearly finished.

*Additional research projects.*—In addition to the items already mentioned some progress has been made on a revision of specifications for copper-base casting alloys, on a study of the effect of impurities on bearing bronzes, on exposure tests of art bronzes, endurance tests of metals, test methods for foundry sands, accelerated corrosion testing, corrosion of locomotive boilers, and a study of the crystal structure of metals.

#### HIGH-TEMPERATURE INVESTIGATION (\$10,200)

*Freezing point of platinum.*—The freezing point of pure platinum was found to be  $1,773^{\circ}$  C. on the international temperature scale. It is estimated that the result is not in error by more than  $2^{\circ}$  C.

*Freezing point of bismuth.*—The freezing point of bismuth of very high purity was determined with a platinum resistance thermometer as  $271.3^{\circ}$  C. on the international temperature scale.

*Thermoelectric properties of metals and alloys.*—The electromotive force against platinum of a series of platinum-rhodium alloys with rhodium content from 1 to 100 per cent was determined last year from  $0^{\circ}$  to  $1,200^{\circ}$  C. This year the investigation has been extended to include a series with rhodium from 0.001 to 1 per cent.

The electromotive force against platinum of nickel of very high purity and of spectroscopically pure zinc and cadmium was determined from  $0^{\circ}$  C. up to the melting points of these metals.

*Investigation of pyrometer protection tubes.*—The rate of passage of air through the walls of pyrometer protection tubes at a series of temperatures up to  $1,300^{\circ}$  C. was determined for 51 primary tubes of 14 different types and 17 secondary (metal) tubes of 8 different types, representing practically every type of pyrometer tube used in this country.

The investigation showed that, in general, if a tube was gas-tight at room temperature, it was practically gas-tight up to the maximum temperature at which the tubes were tested.

*Miscellaneous.*—Other investigations under way include: Determinations of freezing points of several metals, correlation of high temperature tests of dental gold alloys, effect of high temperature on mica and special refractories, and methods for making ceramic shapes for laboratory use.

#### SOUND INVESTIGATION (\$11,260)

*Acoustic properties of building materials.*—An improvement in method has been effected by which sound-absorption measurements are taken by means of instruments, eliminating the variable human ear as a factor. The study of soundproof walls for airplane cabins has been continued, and some 20 combinations have been tested. These have not given better results than those tested last year and described in the bureau's Journal of Research for May, 1929.



*Ultrasonic waves.*—Experiments have been conducted on the speed of ultrasonic waves in certain liquids. By means of measurements of this character it is possible to determine the adiabatic compressibility of a liquid and of a solid suspended in a liquid in which it does not dissolve.

#### INDUSTRIAL RESEARCH (\$204,000)

*Storage-battery construction and operation.*—Attention has been devoted to the use of lead oxides whose physical and chemical properties have been the subject of previous study. Experimental work has been done on pasting formulas, pickling, and formation of storage-battery plates. Batteries have been assembled from these plates and tested for electrical characteristics. Equipment for the automatic control of such tests, by which it is hoped to increase the output but decrease the labor of making the tests, has been designed.

*Insulating liquids.*—Four insulating liquids of high purity have been prepared, namely, pentane, hexane, heptane, and octane. Apparatus for measuring the conductivity of liquids after distillation in a vacuum has been assembled and tested.

*Landing altimeter.*—Altimeters of the aneroid type were tested for drift, seasoning, secular error, and temperature errors with special reference to their use during the landing of aircraft. Flight tests were also made. When using sensitive altimeters of the best quality now available and applying such of the instrumental corrections as are determinate, a residual uncertainty equivalent to about 40 feet in altitude was found to exist.

*Wind pressure on structures.*—Additional measurements of wind pressure have been made on the power-plant stack, and a paper has been prepared giving all the information available on the wind pressure on circular cylinders and chimneys.

Measurements of the distribution of wind pressure over a model of one type of factory building at several angles to the wind have been completed in the 10-foot wind tunnel. The wind force on a model of a wooden oil derrick has been measured.

*Orifice-meter investigations.*—In cooperation with the American Gas Association further experiments have been made on natural gas at high pressures and on the effects of pipe size. The Chicago tests of large gas meters with air have been analyzed and a report on them is in preparation.

*Heats of combustion of hydrogen, methane, and carbon monoxide.*—With a new and improved type of calorimeter the heats of combustion of the above gases have been measured with a high degree of precision. Preliminary values to which certain small corrections have yet to be applied are as follows:

International joules per mol 30° C.	Formation of H <sub>2</sub> O	Combustion of CO	Combustion of CH <sub>4</sub>
Best value.....	285,610	282,900	889,600
Number of good observations.....	18	7	5
Average deviation..... per cent.	-0.02	0.03	0.03
Maximum deviation..... do.	-.05	.07	.07
Difference from previously accepted values..... do.	-.05	-.45	+.75



*Properties of steam.*—Values have been obtained for the heat content of saturated water from  $0^{\circ}$  to  $270^{\circ}$  C., and for latent heat of vaporization and heat content of saturated steam from  $100^{\circ}$  to  $270^{\circ}$  C.

*Gas analysis.*—Several improvements in apparatus for volumetric gas analysis have been developed, including a method of controlling the flow of mercury into the burette, a pipette in which the gas is forced through a perforated platinum plate into the absorbing reagent in the form of very fine bubbles, a compensator with the manometer inclosed to reduce fragility, and improved means for cleaning the contact and opening the compensator to air, a new method of lighting the meniscus to permit greater accuracy in reading volumes, and several details of mounting.

*Thermal conductivity of insulating materials at ordinary temperatures.*—An important feature of this work is the demonstration that the arrangement of fibers has a very large effect on the insulating value of a mass of packed fibers.

Work in cooperation with the American Society for Testing Materials showed that samples of rubber-graphite compositions are suitable standards for the comparative measurement of the thermal conductivity of electrical insulating materials.

In cooperation with the Celotex Co. the temperature coefficients of conductivity, through the range  $-30^{\circ}$  C. to  $+80^{\circ}$  C., of a number of typical insulating and building materials were determined.

*Theory of heat conduction.*—A note on the theory of heat conduction, published in the Journal of Research, outlines a method whereby the solution of many problems of steady heat flow with variable conductivity can be obtained directly from the solutions of the same problems with constant conductivity.

*Heat transfer through building walls.*—Heat transfer through a number of types of walls used for dwelling houses and other small buildings has been measured. The thermal resistances of the various components of completed walls have been determined, so that the insulating value of any particular combination can be calculated.

*Properties of petroleum products.*—In cooperation with the American Petroleum Institute, measurements have been made of the compressibility and thermal expansion of 14 petroleum oils at pressures 1 to 50 atmospheres and temperatures  $0^{\circ}$  to  $300^{\circ}$  C. Practical working tables have been prepared whereby the change in volume of an oil with temperature and pressure may be determined readily with a knowledge of specific gravity and viscosity at standard temperatures.

*Oiliness of lubricating oils.*—Experiments on the Herschel oiliness machine have confirmed the existence of a finite speed at which there occurs a maximum coefficient of friction. Further studies with this machine have shown an average reduction of 20 per cent in the friction of mineral lubricating oils due to the addition of 2 per cent of fatty acid.

*Engine tests of lubricating oils.*—Refinements in the methods used for standardizing tests on lubricating oils were made for the Quartermaster Corps of the Army. Engine-operating conditions are automatically recorded throughout the test periods.

*Journal-bearing performance.*—In cooperation with the American Society of Mechanical Engineers, the effect of the length of the bearing and closeness of fit on friction losses has been determined for a series of 21 different sets of journal bearings.

*Cutting fluids.*—Scientific analysis of 12,000 returns from 68 of the largest users of cutting fluids showing current machine-shop practice has been completed and reported to the American Society of Mechanical Engineers, as a step in a cooperative program for improving the efficiency of metal-cutting operations.

*Wear-resistant alloys.*—The behavior of identical materials when subjected to "wear" in a variety of ways has been studied to establish reliable test methods for determining relative wear resistance of metals. The results emphasize the importance of fitting the testing procedure to the conditions of wear in service.

*Heat-resisting alloys.*—Cooperative work has continued with the American Society for Testing Materials and American Society of Mechanical Engineers in correlating test results obtained by workers in a number of different laboratories on identical metallurgical products. Results of long-time tension tests of metals at high temperatures have been coordinated with similar short-time tests. Data on the suitability of various materials for the construction of apparatus for high-temperature service were published.

*Solubility of gases in metals.*—The equilibrium relations existing between carbon and oxygen in liquid iron at 1,550° to 1,600° C., and the relation between the carbon and oxygen content of the liquid iron and the composition of an overlying gaseous mixture of CO and CO<sub>2</sub> at a total pressure of 1 atmosphere have been studied using the vacuum-fusion and the "residue" methods of analyses developed by the bureau.

*Quenching media for steel.*—Sodium silicate—"water glass"—has been used to quench steel. The results indicate that it is a useful quenching medium with a "cooling velocity" intermediate between water and oil.

*Abrasion tests for rubber.*—Standard abrasion-test methods for rubber have been established involving the development of a standard and easily reproducible comparison compound. In order to check the uniformity of the different lots of standard compound an abrasive track sufficient for several thousand tests without appreciable change has been installed. By maintaining standard test samples at all times for comparison it should be possible to include an abrasion test in several of the Federal specifications where such a test is much needed.

*Antioxidants in rubber compounds.*—A series of aging tests has been made on rubber compounds containing commercial antioxidants. The results show that under practically every condition to which rubber compounds are ordinarily subjected, these materials retard deterioration, although under some of these conditions the effect is much more pronounced than in others.

*Effect of humidity and temperature on the properties of rubber compounds.*—In cooperation with the American Chemical Society, an Outline of Standard Laboratory Procedure for the Preparation and Physical Testing of Rubber Samples has been published.



*Acid in leather.*—The investigation of the effects of sulphuric acid on vegetable-tanned leather shows that leather tanned with one of the catechol tanning materials possesses a high degree of resistance to deterioration by acid, while leather tanned with a pyragallol tanning material shows a low resistance. The influence of the degree of tannage on the deterioration by acid has been studied; and, although the high degree of tannage leathers deteriorate more rapidly the influence of this factor is not as great as the type of tanning material. The rate of deterioration rapidly increases with relative humidities above 80 per cent. Grease content influences deterioration but little even for leathers containing from 10 to 20 per cent of cod oil and tallow. It has been shown that certain leathers take up sulphur groups from polluted atmospheres in sufficient quantities to cause deterioration, thus demonstrating the need for means of preserving leather which was originally satisfactorily made. A laboratory test to determine the hydrolysis of leathers when digested with acid has been devised and the results obtained follow very closely the trends shown in the actual aging tests.

*Sole leather.*—Chrome leather which has been retanned with vegetable tanning materials will wear from 25 to 75 per cent longer than ordinary vegetable-tanned leather, depending upon the extent of the retannage. Those heavily retanned so as to resemble more nearly vegetable-tanned leather showed the least increase in comparative wear. Further work has been started to determine whether the added durability of heavily retanned leathers may not be obtained more economically by using curried or flexible vegetable leathers.

*Specifications and properties of leather.*—It has been found that in the case of split leathers the grain portion possesses very little strength since the strength-giving fibers lie in the flesh portion. The failure of many leathers in service is attributed to excessive splitting off of these strength-giving fibers and emphasizes the need of careful attention to splitting on the part of the tanner and shoe manufacturer.

*Properties of electrical insulating materials.*—It has been found that the electrical properties of rubber slowly change with time when there is a sudden change in temperature or pressure.

*Heterogeneity of pyrex glass.*—Refractive index measurements on various prisms cut from a pyrex glass disk show that a striated non-optical glass may be very uniform in its average optical density and indicate that such optical measurements may be made with high precision and thus be used to supplement or replace mass-density determinations which have been used almost exclusively when investigating variations in the properties of commercial glasses.

*New instrument for testing photographic lenses.*—Good progress has been made on the design and construction of a new lens-testing apparatus which, by a series of exposures on a single plate, will give complete information regarding the performance of a photographic lens. This is very important in connection with airplane mapping.

*Resolving power and sensitivity of motion-picture film.*—Representative developer formulas of the types recently coming into use for reduction of "graininess" of motion-picture films were investigated for their value in spectrography and other scientific uses demanding the optimum combination of resolving power and sensitivity.



It was found that resolving power is not susceptible to any considerable improvement by development methods.

*Spectral sensitization of photographic materials.*—The spectral sensitization produced by bathing photographic plates with mixtures of two important dyes used for this purpose, pinacyanol and pinaflavol, was investigated. Conditions causing coagulation of the dye bath and changes in relative and absolute effectiveness of the two were determined.

*Specific gravity balance.*—The development of the improved specific-gravity balance was completed. The new equipment was given a trial in field use, and has been adopted as the official standard by the Natural Gasoline Association of America.

*The phase equilibrium diagram for the system  $\text{Cr}_2\text{O}_3\text{--SiO}_2$ .*—The diagram has been determined and is characterized by complete non-miscibility of the two components in the liquid state. The melting point of  $\text{Cr}_2\text{O}_3$  has been determined in an oxidizing atmosphere and found to be  $2,140^\circ \text{C}$ ., a value materially higher than any previously reported.

*Spectrochemical analysis.*—Besides numerous spectroscopic tests of metals, alloys, precipitates, etc., researches on the structures of certain spectra have given information as to the lines which may be expected to be most sensitive for this purpose. New descriptions of the spectra of lutecium have made an analysis of their structures possible. This is the first of the 14 rare-earth elements to succumb to this method of analysis.

*Atomic structure investigations.*—Studies of the photo-electric effect in metal vapors, particularly caesium vapor, have shown that the sensitivity extends far beyond the range predicted by theory. The mechanism of this anomalous sensitivity is found to involve a photochemical reaction between the atoms which are excited by absorption of light and other atoms, and the constants of these reactions have been studied.

*Identifications.*—Increased attention has been given to the identification of questioned documents, bullets, and firearms which have been or are to be submitted in evidence in cases in which the United States Government is a party at interest. The testimony of the bureau's experts has been directly responsible for saving the Government very large sums of money.

*Thermal resistance of nickel-chromium-iron alloys.*—Most of the alloys investigated have been found resistant to heat up to  $1,000^\circ \text{C}$ .

*Thermal expansion of carboloy.*—Data on the thermal expansion of carboloy, a tungsten carbide containing cobalt, have been obtained at various temperatures between  $20$  and  $400^\circ \text{C}$ .

*Additional projects.*—Progress has also been made on the following investigations: Regularities in spectra, development of a stereoscopic thread gage, refractive changes produced by heat treatment of glass, recombination of ions and electrons, vapor pressure of carbon dioxide, specific volume of carbon dioxide, expansion and compressibility of crude oils saturated with methane, spontaneous generation of heat in materials, measurement of thermal conductivity of metals at high temperatures, specific heats of organic materials at low temperatures, standard methods for testing brake linings, antifreezing liquids for automobile radiators, consistency of plastic

materials, standardization of hardness of grease, fluidity of oils at low temperatures, load-carrying capacity of journal bearings, efficiency of gears, combustion of carbon monoxide, heat capacities of aqueous solutions, factors involved in silver plating, microscopy of organic compounds for identification purposes, development of thermal expansion apparatus, and precision screw cutting and ruling machine.

*Research associates.*—Table 2 gives the names of associations and manufacturers cooperating with the bureau under the research associate plan, together with the number of associates and the problems on which they are engaged.

TABLE 2.—*Research associates at the Bureau of Standards*

Assigned by—	Num- ber	Specific project
American Association of Textile Chemists and Colorists, W. E. Hadley, secretary, care of Clark Thread Co., Newark, N. J.	1	Assisting in study of methods for testing fastness to light of dyed fabrics.
American Chemical Society, rubber section, Mills Building, Washington, D. C.	1	Physical testing of rubber.
American Dental Association, 58 East Washington Street, Chicago, Ill.	2	Study of dental materials.
American Electric Railway Association, R. H. Dalglish, president, Capital Traction Co., Washington, D. C.	1	Lubrication of journal bearings.
American Face Brick Association, 130 North Wells Street, Chicago, Ill.	2	Face brick absorption and transverse compression; efflorescence.
American Foundrymen's Association, Cleveland, Ohio....	1	Liquid shrinkage in metals.
American Gas Association, 342 Madison Avenue, New York, N. Y.	3	Research on gas; corrosion of pipe lines.
American Institute of Steel Construction, New York, N. Y.	1	Fire tests on battle deck floor construction.
American Petroleum Institute, 250 Park Avenue, New York, N. Y.	8	Properties of petroleum products.
American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York, N. Y.	7	Steam-table research and high-temperature measurements.
American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa.	2	Research in cement; testing.
American Standards Association, 29 West Thirty-ninth Street, New York, N. Y.	3	Development of instruments and methods for testing elevator-safety equipment.
Asphalt Shingle and Roofing Institute, 2 West Forty-fifth Street, New York, N. Y.	1	Relative values of different fibers used in roofing felts.
Associated Knit Underwear Manufacturers of America (Inc.), 329 Main Street, Utica, N. Y.	1	Standardization and simplification of underwear sizes; methods of manufacture.
Atlas Lumnite Cement Co., 25 Broadway, New York, N. Y.	2	Research in cement; testing, etc.
Brown Co., Berlin, N. H. ....	2	Permanency of paper.
Bunting Brass & Bronze Co., 715-755 Spencer Street, Toledo, Ohio.	2	Testing of bronze.
Bureau of Efficiency, Washington, D. C. ....	1	Routine testing of paper.
Cast Iron Pipe Research Association, 566 Peoples Gas Building, Chicago, Ill.	1	Investigation of causes of soil corrosion.
Celotex Co., 645 North Michigan Avenue, Chicago, Ill....	1	Heat transfer of building-insulating materials.
Cerro de Pasco Copper Corporation, 44 Wall Street, New York, N. Y.	1	Development of new uses for metallic bismuth.
Committee on Glass, E. C. Sullivan, chairman, Corning Glass Works, Corning, N. Y.	1	Physical properties of glass.
Common Brick Manufacturers of America, 2121 Guarantee Title Building, Cleveland, Ohio.	2	Moisture transmission of brick walls.
Copper and Brass Research Association, 25 Broadway, New York, N. Y.	1	Corrosion of copper roofing materials.
Cooper, Hugh L., Co. (Inc.), 101 Park Avenue, New York, N. Y.	3	Use of clays in concrete mixtures.
Cotton Textile Institute (Inc.), 320 Broadway, New York, N. Y.	1	Study of specific uses for cotton materials.
Dardelet Thread Lock Corporation, 120 Broadway, New York, N. Y.	3	Locking devices for screw threads.
Indiana Limestone Association, Bedford, Ind. ....	1	Study of physical properties of Bedford limestone.
International Association of Electrotypers, Dan A. Hoynes, 1760 East Twenty-second Street, Cleveland, Ohio.	1	Plating of electrotypes.
Marine Underwriters' Committee, 82 Beaver Street, New York, N. Y.	1	Investigation of spontaneous ignition of jute fibers, etc.



TABLE 2.—*Research associates at the Bureau of Standards—Continued*

Assigned by—	Number	Specific project
Midvale Co., Philadelphia, Pa.-----	1	Properties of metals at high temperatures.
National Association of Glue Manufacturers, J. R. Powell, secretary, care of Armour Glue Works, 1355 West Thirty-first Street, Chicago, Ill.	1	Use of glue in paper sizing.
National Association of Hosiery and Underwear Manufacturers, 334 Fourth Avenue, New York, N. Y.	2	Study of methods of manufacture of hosiery and knitted goods.
National Lead Co., 105 York Street, Brooklyn, N. Y.-----	1	Research in pigments.
National Research Council, Washington, D. C.-----	11	Radio; insulating materials; deterioration of paper; gumming of petroleum; mechanics, etc.
National Terra Cotta Society, 19 West Forty-fourth Street, New York, N. Y.	3	Investigation of architectural terra cotta.
Non-Ferrous Ingot Metal Institute, 308 West Washington Street, Chicago, Ill.	1	Nonferrous ingot metal research.
Portland Cement Association, 111 West Washington Street, Chicago, Ill.	8	Constitution and hardening of Portland cement.
Society of Automotive Engineers, 29 West Thirty-ninth Street, New York, N. Y.	7	Cooperative fuel research.
E. R. Squibb & Sons Co., New Brunswick, N. J.-----	2	Investigation of antifreeze mixtures.
Steel & Tubes (Inc.), 224 East One Hundred Thirty-first Street, Cleveland, Ohio.	1	Tension, compression, elongation, deformation, etc., tests of tubes.

**TESTING RAILROAD-TRACK AND OTHER SCALES (\$48,900)**

*Calibration of test cars.*—Fifty-five calibrations were made on 17 self-contained and 8 compartment-type track scale test weight cars at the master-scale depot at Clearing, Ill. In 17 of the calibrations the cars were found to be heavy and in 38 the cars were found to be light. The average error of self-contained cars was 9.5 pounds and that of compartment-type cars was 58.6 pounds.

*Cooperation with industrial technical groups.*—The bureau cooperated with the National Scale Men's Association, the National Scale and Balance Manufacturers' Association, and the American Railway Engineering Association in the development of specifications for railway-track scales and test-weight cars.

Formal committee contact has been maintained with the American Railway Engineering Association on matters relating to railway weighing machinery and methods of use.

*Master-scale tests.*—Sixteen of the 19 master-track scales in the United States were calibrated. One master scale at Reading, Pa., was retired and replaced with a new installation.

*Railroad-track scales.*—Eight hundred and fifty railroad-track-scale tests were conducted, an increase of about 15 per cent over the preceding year and about 20 per cent over the fiscal year 1928. Of the scales tested 71.8 per cent were within the bureau's tolerance of 0.20 per cent. The average weighing error for the scales tested was 0.21 per cent, or slightly more than the above-cited tolerance. The figures are substantially the same as those for recent years. Scales owned by railroads generally exhibit better weighing performance under test than those owned by industry or commercial organizations. The differences may be ascribed to the fact that the railroads maintain special departments to keep their weighing equipment in proper order.

The comparative standing of the eastern, southern, and western districts with regard to the proportion of correct scales is represented by the respective values, 72.3, 64.4, and 79.3 per cent.



*Track scales for weighing grain.*—A separate analysis made of test results for 41 track scales in grain-weighing service indicates that on the basis of the 0.10 per cent tolerance, 21 scales, or 51.2 per cent of the total, were correct. For the entire group, the average weighing error was 0.14 per cent. Comparatively few track scales in grain-weighing service even at terminal markets conform to the type specified for this work, whereas in other lines, such as in the "origin" weighing of coal at Great Lakes ports, nearly all scales are of approved-specification type. Out of 27 of such scales tested 85 per cent were correct within the regular tolerance of 0.20 per cent.

*Test-car calibrations in field.*—The weights of 24 track scale test cars were restandardized for railroads or industries which do not have master-scale facilities.

*Track-scale census.*—The railways of the country were circularized to secure a revised census of railroad-track scales and the returns will be used in revising the office records and in working up a new map system. The returns indicate that the number of track scales now in use is roughly 25 per cent less than in 1925 when the last census was taken. There are now approximately 3,800 railroad-owned scales and 5,200 industry-owned scales.

*Cooperation with States in weights and measures matters.*—Formal State conferences were attended in California, Illinois, Maine, Massachusetts, Michigan, New Jersey, New York, Ohio, and Pennsylvania; informal conferences were held with officials in Connecticut, Delaware, Illinois, Indiana, Minnesota, Nebraska, Nevada, New Hampshire, New Jersey, North Dakota, Oregon, Pennsylvania, Utah, Vermont, Washington, Wisconsin, and Wyoming, travel in these cases being largely incident to attendance at formal meetings.

Preparation of a digest of weights and measures court decisions has been continued, and a publication was issued describing equipments in use by officials for the testing of large-capacity scales.

*Cooperation with other Government departments.*—Frequent consultations have been held with representatives of other Federal departments on weighing or measuring problems and equipment, and numerous weighing and measuring devices have been tested or examined for these agencies, both in Washington and at Clearing.

#### STANDARDIZATION OF EQUIPMENT (\$220,000)

*General conferences on simplified practice.*—Fifteen general conferences were held to adopt simplified-practice recommendations. Simplified-practice recommendations covering 113 commodities have been approved and adopted by the industries affected, while others are in the process of acceptance. Printed recommendations have been issued for 100 commodities.

*Revision and reaffirmation conferences.*—Thirty-nine conferences of the standing committees took place to consider the desirability of revising existing simplification programs. Thirty-four recommendations, or 85.3 per cent of the total number reviewed, were reaffirmed, without change, for another year. This compares favorably with the figures for last year, during which 31, or 75.5 per cent, of the 41 recommendations reviewed were reaffirmed.

*Adherence to simplified practice recommendations.*—Surveys of production, distribution, and use showed that the average adherence to simplified practice recommendations covering 25 commodities was 86.7 per cent. In 1929, the percentage for 26 commodities averaged 85.43.

TABLE 3.—*Degree of adherence determined by actual survey*

S. P. R. No.	Commodity	Degree of ad- herence	S. P. R. No.	Commodity	Degree of ad- herence
		<i>Per cent</i>			<i>Per cent</i>
1	Paving brick.....	87.8	55	Tinware, galvanized, and japanned	
2	Bedsteads, springs, and mattresses.....	91		ware.....	90
4	Asphalt.....	89.4	62	Metallic cartridges.....	99
10	Milk bottles and milk-bottle caps.....	79	63	Metal spools.....	43
11	Bed blankets.....	90.5	66	Automobile brake lining.....	78.9
12	Hollow building tile.....	89.5	67	Roller bearings.....	58
13	Structural slate.....	63.7	68	Metal and fiber flash-light cases.....	93
14	Roofing slate.....	94.5	73	1-piece porcelain insulators.....	91
15	Blackboard slate.....	95.6	76	Ash handles.....	89
24	Hospital beds.....	91.3	77	Hickory handles.....	80.6
30	Roofing ternes.....	100	88	Floor sweeps.....	96.5
31	Loaded paper shot shells.....	99.5	98	Photographic paper.....	96.6
43	Paint and varnish brushes.....	83.7			
49	Sidewalk, floor, and roof lights.....	98.2		Average.....	86.7

*Variety surveys in progress.*—Upon request, 34 preliminary conferences were organized for 32 different industries. In consequence, surveys of existing overdiversification of product were instituted by simplified-practice committees appointed by 16 of those industries. Similar activity is contemplated by the other 16 groups.

*Simplified practice and distribution.*—Simplification of material-handling equipment and containers in general has recently received attention. A field study of wrapping and packing methods and supplies used in department stores is in progress. Upon request, the bureau has surveyed 34 department stores, located in 17 cities throughout the United States.

*Directory of governmental laboratories.*—As the result of a request from the War Department, the chief coordinator arranged for the preparation by the bureau of a classified list of all governmental laboratories, facilities, etc., available for the testing of supplies and materials for the purchasing officials of the various governments.

*Encyclopedia of specifications.*—Manuscript for the second volume of the encyclopedia series, entitled "Standards and Specifications for Nonmetallic Minerals and Their Products," was revised to bring it down to date and will soon be published. This is a companion volume to Standards and Specifications in the Wood-Using Industries, already published, and Standards and Specifications for Metals and Metal Products, the manuscript of which is now in preparation.

*Cooperation with public purchasers.*—In its compilation of the Encyclopedia and the Directory of Commodity Specifications, and in collecting material for the Standards Yearbook, the bureau has established contacts with more than 25,000 public purchasers.

*Facilitating the use of specifications.*—In order to facilitate the use of Federal specifications and commercial standards by governmental purchasing agencies, there has been sent to these agencies names and addresses of more than 3,000 "willing-to-certify" manufacturers. The following common commodities are now covered: Abrasives



and polishing materials; brick, common; brushes and brooms; builders' hardware; cement, Portland; commercial standards; dental and surgical supplies; electrical supplies; fire extinguishers and liquids; floor coverings; glass; heat-insulating materials; inks; leather goods; lime and plaster; liquid-measuring devices; lumber, softwood; packing and gaskets; padlocks; paints and paint materials; paper; pipe and pipe fittings; refractories; ribbons, typewriter; road and paving materials; roofing, bituminous, and waterproofing; rope, wire; safes, burglar-resisting; scales, railroad track; scales, weighing; screws, wood; soaps and scouring compounds; tableware, silver-plated; textiles; and tubing, metallic.

*Commercial standards.*—Five general conferences were held, covering the following subjects: Plain mohair-upholstery plush, red-cedar closet linings, plate-glass mirrors, interchangeable ground-glass joints, and feldspar.

A satisfactory majority of acceptances have been received to warrant the success of the following 16 projects: Diamond-core drill fittings, plain and thread plug and ring gage blanks, builders' hardware (nontemplate), builders' template hardware, dress patterns, men's pajamas, foundry patterns of wood, standard screw threads, special screw threads, standard weight malleable iron or steel screwed unions, feldspar, interchangeable ground-glass joints, domestic and industrial fuel oils, hickory golf shafts, wall paper, and staple vitreous-china plumbing fixtures.

The 12 following commercial standards have been issued in printed form: Wrought-iron pipe nipples (CS6-29), standard weight malleable iron or steel screwed unions (CS7-29), builders' template hardware (CS9-29), brass pipe nipples (CS10-29), regain of mercerized cotton yarns (CS11-29), domestic and industrial fuel oils (CS12-29), dress patterns (CS13-30), men's pajamas (CS15-29), wall paper (CS16-29), diamond-core drill fittings (CS17-30), hickory golf shafts (CS18-29), and foundry patterns of wood (CS19-30).

*Safety codes.*—In cooperation with a committee of national scope, a new edition of the Elevator Safety Code has been prepared. Members of the staff have participated actively in the work of the safety code correlating committee and in sectional committees preparing and revising safety codes for various industries. Revisions of the factory-lighting code and the code for abrasive wheels were completed by such committees. Work was continued on codes dealing with walkway surfaces; conveyors and conveying machinery; cranes, derricks and hoists; mechanical refrigeration; industrial sanitation; mechanical power transmission; and traffic signs and signals. Assistance was given various States in the preparation of local regulations. A survey of accidents in the homes of club women in North Carolina was made as a preliminary to a movement in cooperation with the General Federation of Women's Clubs to reduce accidents in the home.

*Heating radiators.*—The original program of work on cast-iron tubular-type radiators was completed. This included determinations of effectiveness and heat dissipating ability of the various commercial sizes of radiators of this type. The general conclusion was that the size and style influenced the effectiveness, but not to any great extent. Apparatus was constructed with which to test radiators of the fin-convective type.



*Algebraic computation of spherical aberration.*—The investigation of algebraic methods for computing the aberrations of lenses has been continued. For spherical aberration a new system of formulas has been developed. These are in a form suitable for use with a computing machine.

*Dry-cell standardization.*—The qualification tests made primarily in connection with Government purchases have been continued, and have included samples from practically all makers of dry cells in this country. The mechanical equipment for controlling the tests makes it possible to test a large number of batteries with a minimum amount of labor. Results of these tests have served as a basis for a revision of the American Standard for dry cells and also for a revision of the Federal specification.

*Specifications for storage batteries.*—Automotive storage batteries are now covered by a specification which was completed and ready for transmission to the Federal Specifications Board at the close of the year. Progress has been made in the preparation of a standard specification for sulphuric acid and battery electrolyte.

#### STANDARD MATERIALS (\$10,600)

During the year 7,592 samples were distributed, having a sales value of \$16,764, and approximately \$73,073 worth of standard samples were added to the salable samples on hand. The standard samples include ores, ceramic and metallurgical products, and pure chemicals, and are used to check methods of chemical analysis that control the manufacture and sale of metallurgical, ceramic, and agricultural products; to calibrate scientific instruments; and to further research in methods of analysis. A direct result of the use of the samples is a saving of thousands of dollars a year through improved manufacturing operations and the avoidance of costly disputes based on faulty analyses. The standard sample fund is unique in that the return to the United States Treasury in fees and accumulated stocks of salable samples has always far exceeded the appropriation.

#### INVESTIGATION OF RADIOACTIVE SUBSTANCES AND X RAYS (\$31,500)

*Cosmic radiation.*—Certain results of experiments using three Geiger-Mueller tube counters placed vertically one above the other, with a strong magnetic field introduced between the two lower counters, are interpreted as indicating that cosmic radiation consists of electrified particles with velocities corresponding to  $10^9$  volts accelerating potential.

*Development of X-ray standards.*—A service for the precise calibration of X-ray dosage meters has been established, and a number of instruments have been calibrated for cancer hospitals.

A portable secondary standard X-ray ionization equipment of weight and volume about one-fifteenth that of the standard equipment has been developed for comparing the standards in this country and abroad—a condition heretofore impossible of attainment with sufficient accuracy.

*Study of X-ray generators.*—In cooperation with a number of manufacturers an investigation of X-ray equipment, including that in hospitals, is in progress.

*Measuring high direct-current potentials of X-ray generators.*—Up to the present, the spark gap has been used almost exclusively for this purpose, with inadequate accuracy. An equipment of the voltmeter-multiplier type with an error of only two-hundredths of 1 per cent has been devised, constructed, and found entirely satisfactory for measuring the rippled voltage furnished by X-ray generators.

*Radium testing.*—Eleven hundred and seventy-three preparations of radium, totaling nearly 10,000 milligrams of the element, and fixing a sale value of about \$650,000 were tested; also, 67 samples of luminous material were measured for brightness.

*Other investigations.*—Progress has also been made on the following investigations:  $\alpha$ -ray tracks in various gases; a possible relation between the energy levels and the magnetization of an iron atom; dosage measurement in X-ray therapy; the nature of the action of the Geiger counter; quality determination of X rays; cathode-ray dosimetry; X rays from thin targets; deflection of cathode beams by thin metal foils; functioning of X-ray equipment; and study of mechanism of electrical conduction of rarefied gases.

#### UTILIZATION OF WASTE PRODUCTS FROM THE LAND (\$52,700)

*Utilization of cornstalks and wheat straw.*—In the manufacture of wall board from cornstalks, new types of machinery have been tried out in a successful effort to find the best-suited equipment for this purpose. Wall board has been made having a thickness of one-half inch and twice as strong as any insulating board on the market. An insulating board 2 inches thick without lamination has been made for use in refrigerators.

From a process developed at the bureau a material called "maizolith" has been produced from cornstalks, which has many characteristics of hard rubber or vulcanized fiber.

The work on the manufacture of paper from straw pulp is being continued in an effort to improve the quality of the paper produced. Samples of pulp have been forwarded to Washington and made into paper and the paper tested. New quarters have been established and new equipment is being installed for the continuation of this work.

*Manufacture of xylose.*—In cooperation with the University of Alabama, the Alabama Polytechnic Institute, and the Alabama Industrial Development Board, a semicommercial factory was successfully operated at the plant of the Federal Phosphorus Co., Anniston, Ala., for the manufacture of xylose from cottonseed-hull bran, and other raw materials such as peanut shells and corncobs.

By a process developed in the laboratory in Washington, xylose was manufactured at the rate of 100 pounds per day. The crude xylose was given a purification and recrystallization treatment which rendered it 99.99 per cent pure.

Samples of xylose have been forwarded to individuals and concerns all over the world who are cooperating in the investigation of

its possible use in the dyeing and tanning industries, in foodstuffs, in explosives, for manufacture of chemicals, of alcohol to be used as solvent for lacquer, etc.

*Miscellaneous.*—A preliminary investigation of artichoke tops was conducted and a very good grade of board was obtained therefrom. The utilization of sugars from the waste products of corn was studied as well as the separation of glycosides by means of calcium chloride addition compounds.

#### INVESTIGATION OF AUTOMOTIVE ENGINES (\$26,500)

*Automobile-engine acceleration.*—From tests made in cooperation with the American Petroleum Institute, the National Automobile Chamber of Commerce, and the Society of Automotive Engineers with the portable spark accelerometer on a number of representative automobile engines at the laboratories of the companies manufacturing them, it was concluded that the effect on acceleration of fuel volatility is qualitatively independent of engine design.

*Antiknock characteristics of fuels.*—To secure uniformity in expressing antiknock value, the subcommittee on methods of measuring detonation, appointed by the cooperative fuel-research steering committee with which the bureau is cooperating, has recommended that all laboratories be invited to express their present knock-rating scales in terms of octane numbers. The octane number of a gasoline is defined as the number of parts by volume of iso-octane that must be added to 10 parts of normal heptane to produce a blend of equivalent detonation characteristics.

The antiknock investigation is now the major problem of the joint motor-fuel research supported cooperatively by the American Petroleum Institute and the National Automobile Chamber of Commerce through the Society of Automotive Engineers.

*Vapor lock in airplane fuel systems.*—It has been found that for gasoline which does not contain appreciable amounts of propane the vapor-locking temperature is equal at sea level to the American Society for Testing Materials 10 per cent point and decreases about 2° F. for each 1,000 feet altitude. The effect of weathering of the gasoline on the vapor-locking tendency has also been studied. Data on temperatures which exist in fuel lines during flight are being secured through cooperation with the Army, the Navy, and the National Advisory Committee for Aeronautics.

*Gumming characteristics of gasoline.*—Gum in gasolines may cause objectionable deposits in the intake manifold and on the intake valves. The bureau is making a study of the gumming characteristics of gasolines on behalf of the Army Air Corps. New methods of test are being developed since the present procedure is not satisfactory.

*Phenomena of combustion.*—Upward of 3,000 photographic records of the progress of the gaseous explosive reaction as it occurs at constant pressure in a soap bubble used as a bomb have been analyzed to determine the effect of pressure on the rate of the reaction. The experimental data show that for a charge of given



proportions the linear rate of propagation of the reaction zone within the explosive gases is constant and independent of pressure, and that as a result the rate of molecular transformation is proportional to pressure.

*Combustion in an engine cylinder.*—Equipment for making stroboscopic observations of flame movement and simultaneous measurements of pressure development in an engine cylinder has been used to obtain diagrams showing the movement of the flame in all parts of the combustion chamber and the variation of pressure during burning. Such data correlate the more fundamental studies of the gaseous explosive reaction at constant pressure with actual engine performance. The work is in cooperation with the National Advisory Committee for Aeronautics.

*Supercharging of aircraft engines.*—Altitude chamber performance tests of a Curtiss D-12 engine equipped with a Roots-type supercharger, having a critical altitude of 5,000 feet at 2,000 revolutions per minute, were made for the Army Air Corps, and tests with a geared centrifugal supercharger are in progress.

*Oil recommendations.*—A statistical study has been made of the various grades of oil recommended by the automotive vehicle manufacturers and oil refiners for about 200 makes of trucks, tractors, and passenger cars and the results summarized in convenient form for practical use and published by the Chief Coordinator.

*Miscellaneous.*—Work on the following projects is under way: Standard tests for fuels for automotive engines, tests of fuel volatility, tests of miscellaneous devices for automotive transportation, and motor-vehicle tax ratings.

#### INVESTIGATION OF DENTAL MATERIALS (\$5,300)

Government purchases of dental golds, amalgam, alloys, etc., having an estimated value of \$100,000, have been tested. About half this amount has been rejected as unfit for use in service. Replacements have been made and approved. Specifications have been prepared for dental investments and a thorough test made of all investments on the market. Assistance has been given dental schools, manufacturers, and testing laboratories interested in equipping for this type of research. Lectures and clinics have been given in Washington, New York, Boston, Des Moines, Chicago, and Columbus.

One of the most satisfactory aspects of this program is the move by a number of manufacturers to guarantee certain of their products to comply with the specifications adopted by the American Dental Association, through cooperation with the bureau.

#### POWER-PLANT EQUIPMENT (\$100,000)

The boiler-room equipment was completed and that section of the plant was put in full operation at the beginning of the heating season. The principal units of permanent equipment in the engine-room section of the plant have been installed and will be put in operation within a short time.

## TRANSFERRED FUNDS (\$436,387)

*Organization and projects.*—During the year funds were transferred from the following branches of the Government covering the projects listed:

Aeronautics Branch, Department of Commerce	Navy Department—Continued.
Air-navigation aids.	Humidity research.
Aeronautical research.	Battery testing.
Bureau of Engraving and Printing:	Submarine storage batteries.
Electrodeposition.	Production of optical glass.
Paper currency and stamps.	Post Office Department: Development of accelerometers.
Coast and Geodetic Survey: Making of special castings.	Steamboat Inspection Service: Fire-alarm systems.
Coast Guard: Development of radio-receiving sets.	United States Shipping Board:
National Advisory Committee for Aeronautics:	Studies of petroleum.
Aerodynamic problems.	Miscellaneous engineering and physical investigations.
Embrittlement of duralumin.	Miscellaneous chemical investigations.
Duralumin and steel tubes.	War Department:
Aeronautic power plants.	Gasoline investigation.
Substitutes for parachute silks.	Superchargers for aircraft engines.
Navy Department:	Embrittlement of duralumin.
Airship girders.	Radio apparatus for signal service.
Aircraft instruments.	Friction and lubrication studies.
Gas-cell fabrics.	Substitutes for leather.
Carbon and chrome steel.	Substitutes for chromium.
Corrosion investigation.	Nontin metal.
Aeronautic fabrics.	Experimental gages.
Airplane ignition systems.	Development of machine guns.

Many of these projects were supported partly by bureau and partly by transferred funds. The more important of these have already been described under the appropriate bureau fund. Important investigations supported wholly by transferred funds include the following:

*Air-navigation facilities—Radio.*—In cooperation with the Aeronautics Branch, experimental work on the 2, 4, and 12 course visual-type radiobeacons was completed. The sensitivity of the vibrating-reed indicator was increased fourfold. The development of a new transmitter for the simultaneous transmission of radiotelephone messages and visual-type radiobeacon signals on the same radio-frequency was begun. An automatic volume-control device for use in the reception of visual beacon signals was developed, thereby relieving the pilot of the duty of controlling the receiving-set sensitivity.

A complete system of radio aids showing good promise for blind landing of aircraft was developed.

Contact and cooperation with the aircraft and radio industries in the development of engine ignition shielding was maintained. A commercial shielding assembly patterned after an assembly developed by this bureau met with marked success. A direction finder permitting aural or visual indication of the direction of the received signal was developed.

*Lighting of airports and airways.*—Photometric measurements have been made on 24-inch beacons, code beacons, and gaseous-discharge tube beacons, and observations of their visibility have been made from fixed stations and from airplanes. Observations on several types of boundary lights have been made from two distances



by 16 observers. Experiments on the lighting of wind-indicator cones have been continued, and measurements are in progress on aviation red and green signal glasses, for the purpose of preparing specifications.

*Radio-receiving sets for the Coast Guard.*—Apparatus was purchased and developed suitable for determining the electrical sensitivity, selectivity, fidelity, and overload characteristics of radio-receiving sets. The sets tested include 9 submitted as bid samples to the Coast Guard, 3 high-frequency sets for the Navy, 1 intermediate-frequency set for the Bureau of Lighthouses, 4 aircraft radio sets for the aeronautic research division, and 1 set purchased by this bureau.

*Corrosion of storage-battery plates.*—Corrosion of the positive plates in certain submarine batteries has led to a study of the effects of organic material and the conditions under which corrosion of the plates may occur. Conflicting evidence on the effect of acetic acid in storage batteries has been explained, and a method for the determination of small amounts of acetic acid in the presence of large amounts of sulphuric acid has been developed.

*Type testing of commercial airplane engines.*—The engine-testing laboratory at Arlington is operating at full capacity and a fourth torque-stand unit will be added to provide for probable increased demands. Of 52 engines received for test during the year 26 passed, 23 failed, and 3 were withdrawn. This work is supported by the Aeronautics Branch of the Department of Commerce.

*Effect of spark character on ignition ability.*—In cooperation with the National Advisory Committee for Aeronautics and the Bureau of Aeronautics of the Navy Department, the relative effectiveness of ignition sparks has been compared by determining the amount of chemical reaction which takes place when different sparks are passed through an explosive mixture of oxygen and hydrogen at low pressure and liquid-air temperature.

*Effect of air humidity on engine performance.*—An improved form of psychrometer has been developed as a by-product of this work, which is in cooperation with the Navy Department; action to obtain a Government patent will be initiated.

Engine power tests have been made, extending the range of humidity from 1 to 80 millimeters mercury pressure of water vapor. These tests accord with the oxygen-content hypothesis. Results indicate an increase in effectiveness of tetraethyl lead as a knock suppressor at increased humidities. Especial attention was given to the possibility of changes of humidity causing error in knock rating.

*Aircraft-instrument developments.*—A strut thermometer of the electric-resistance type, an improved suspended-head air-speed meter of the commutator-condenser type, and a maximum indicating accelerometer were constructed for the Bureau of Aeronautics, Navy Department. A mooring-force indicator for the airship *Los Angeles* and a suspended Pitot static-head air-speed meter are under development. Investigations to provide a basis for the specification of performance of banking indicators, magnetic compasses, and tachometers were conducted. A standard vibration board was designed and constructed for the purpose of testing aircraft instruments.



*Reduction of noise in airplanes.*—In cooperation with the Aeronautics Branch of the Department of Commerce, studies have been made of the possibilities of reducing noise in airplanes.

*Aileron investigation.*—In cooperation with the National Advisory Committee for Aeronautics and the Aeronautics Branch of the Department of Commerce, the effect of variation of chord and span of ailerons on rolling and yawing moments at high angles of attack has been studied.

*High-speed airfoil tests.*—In cooperation with the National Advisory Committee for Aeronautics, the aerodynamic characteristics of eight airfoils of circular-arc section were determined at speeds up to and slightly above the speed of sound. These airfoils are more efficient at high air speeds than ones of conventional type, and are therefore of advantage in designing high-speed propellers.

*Investigations of wind-tunnel turbulence.*—In cooperation with the National Advisory Committee for Aeronautics the significance of measurements with the hot-wire anemometer has been investigated by studying the transition from laminar to eddying flow around a thin flat plate parallel to the wind.

*High-frequency fatigue testing.*—In cooperation with the National Advisory Committee for Aeronautics, seven air-driven, high-frequency fatigue machines are now operating at frequencies of approximately 200 cycles per second. Each test bar is subjected to 200,000,000 cycles of stress if failure does not occur before this limit is reached.

*Flat plates under normal pressure.*—At the request of the Navy Department, an apparatus was designed and built for testing specimens representing pontoon construction by subjecting them to a normal water pressure.

*Strength of welded aircraft joints.*—To assist the Aeronautics Branch of the Department of Commerce, the strength and efficiency of 40 types of acetylene-welded fuselage joints made of chrome-molybdenum steel tubing were determined. The use of gusset plates welded to the tubes increased the strength about 30 per cent in the case of some types of joints.

*Distinguishing steel airplane tubing of different compositions.*—Preliminary work with the Bureau of Aeronautics and the National Advisory Committee for Aeronautics indicates that a magnetic test and a spark test may give satisfactory results as rapid nondestructive methods for distinguishing between plain carbon and chrome-molybdenum steel tubing. A simple chemical "spot test" appears to be impossible.

*Prevention of embrittlement of sheet duralumin by corrosion and of deterioration of magnesium alloys by corrosion.*—Results of 3-year exposure tests closely confirm laboratory tests in showing the superiority of pure aluminum as a coating material for duralumin and of the necessity of proper heat treatment if maximum corrosion resistance is to be obtained. Laboratory tests have shown the decided advantage gained in coating aluminum alloys by giving the surface a preliminary treatment by the anodic oxidation process. Experiments show that coating magnesium-alloy specimens to resist atmospheric corrosion is a more serious problem than in the case of aluminum alloys.

*Bearing alloys.*—In cooperation with the War Department, a study has been started of lead-base and tin-base bearing alloys for Army trucks. The work will be extended to include the copper-lead bearing materials.

#### ACKNOWLEDGMENTS AND RECOMMENDATIONS

The Congress has recognized the need of several projects recommended in previous reports by making due provisions and appropriations. Thus, the regular appropriations for 1931 contain increases over 1930 for salaries, grounds, structural materials, mechanical appliances, textiles, sugar, gages, metallurgy, industrial research, standardization of equipment, automotive engines, railroad scales, and dental materials, totaling \$263,925. Appropriations for new projects in 1931 include \$350,000 for the hydraulic laboratory, \$75,000 for addition to the shops building, and \$400,000 for additional land. Provision was also made for stationing a medical officer of the Public Health Service at the bureau to eliminate health hazards in certain lines of work and care for emergency-accident cases.

*Radio stations.*—There is pending in the Senate an authorization which has passed the House, making provision for two radio stations at locations removed from extraneous influences. These stations are needed (1) for transmitting continuously standard signals to enable broadcasting stations to check at will their wave lengths and (2) for experimental purposes, particularly with reference to short-wave phenomena.

*New buildings.*—The present buildings of the bureau are greatly overcrowded, and it is urgently recommended that adequate provision be made for expansion. The most urgent need is for an administration building, costing about \$400,000, which would free certain spaces greatly needed in laboratory buildings as well as providing adequate accommodations for the rapidly expanding work of the standardization group and also for the administrative and other general functions of the bureau, including library and conference rooms.

Provision has been made for additional space in Federal buildings at San Francisco and Denver.

There has been previously submitted a 5-year building program, which includes provision for a high-voltage laboratory, fire-resistance laboratory, extension of the dynamometer laboratory, an enlarged low-temperature laboratory, and new laboratories for mechanical engineering and high-precision testing in weights and measures.

As the demands for the bureau's services grow, provision should be made, in Washington and the branch laboratories, to meet these needs by increasing the facilities and personnel engaged in research and testing.

Very truly yours,

GEORGE K. BURGESS,  
*Director Bureau of Standards.*

## APPENDIX

### GENERAL FINANCIAL STATEMENT

During the fiscal year 1930 the bureau expended and accounted for funds aggregating \$2,938,467.62, including \$431,721.62 received by transfer and reimbursement from other departments for special researches.

The amounts and objects of each appropriation for the past fiscal year and two previous fiscal years, together with disbursements, unpaid orders outstanding, and unexpended balances for each appropriation are shown in the following table:

TABLE 4.—*Disbursements, liabilities, etc., 1930, 1929, and 1928 appropriations*

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1930				
Salaries.....	\$686, 146. 00	\$684, 509. 65	\$1, 175. 32	\$461. 03
Equipment.....	88, 000. 00	73, 705. 11	13, 996. 95	297. 94
General expenses.....	<sup>1</sup> 65, 790. 49	56, 925. 25	8, 371. 57	493. 67
Improvement and care of grounds.....	14, 400. 00	14, 230. 58	120. 98	48. 44
Testing structural materials.....	<sup>2</sup> 272, 343. 51	256, 522. 99	15, 742. 39	78. 14
Testing machines.....	41, 000. 00	36, 048. 07	4, 939. 75	12. 18
Metallurgical research.....	<sup>3</sup> 51, 052. 32	45, 827. 59	5, 208. 10	16. 63
Investigation of optical glass.....	27, 300. 00	26, 910. 27	381. 74	7. 99
Standard materials.....	10, 600. 00	10, 045. 56	436. 09	118. 35
Investigation of textiles.....	53, 900. 00	53, 427. 63	440. 93	31. 44
Sugar standardization.....	<sup>4</sup> 78, 900. 00	78, 409. 72	472. 61	17. 67
Gauge standardization.....	40, 000. 00	37, 598. 02	2, 385. 26	16. 72
High-temperature investigation.....	10, 200. 00	9, 548. 64	637. 19	14. 17
Testing railroad scales.....	48, 900. 00	46, 963. 71	1, 418. 61	517. 68
Investigation of fire-resisting properties.....	30, 000. 00	28, 890. 92	1, 009. 19	99. 89
Testing miscellaneous materials.....	46, 400. 00	45, 827. 61	541. 70	30. 69
Investigation of public-utility standards.....	<sup>5</sup> 107, 423. 30	103, 696. 63	3, 724. 81	1. 86
Radio research.....	85, 700. 00	82, 622. 70	2, 718. 46	358. 84
Industrial research.....	<sup>6</sup> 207, 000. 00	192, 300. 96	14, 550. 44	148. 60
Sound investigation.....	11, 250. 00	11, 171. 89	33. 72	54. 39
Investigation of clay products.....	49, 000. 00	46, 777. 30	2, 183. 81	38. 89
Color standardization.....	15, 800. 00	15, 297. 49	495. 11	7. 40
Investigation of radioactive substances and X rays.....	31, 500. 00	27, 768. 11	3, 596. 57	135. 32
Standardizing mechanical appliances.....	29, 300. 00	27, 895. 66	1, 339. 94	64. 40
Investigation of mine scales and cars.....	13, 400. 00	12, 042. 32	1, 057. 51	300. 17
Standardization of equipment.....	<sup>7</sup> 220, 015. 00	205, 750. 22	14, 058. 57	206. 21
Investigation of automotive engines.....	26, 500. 00	26, 102. 36	391. 68	5. 96
Utilization of waste products from the land.....	52, 700. 00	50, 673. 06	2, 016. 12	10. 82
Investigation of dental materials.....	5, 300. 00	4, 435. 86	793. 74	70. 40
Power-plant equipment.....	100, 000. 00	80, 512. 47	19, 055. 03	432. 50
Appropriations transferred from other departments which are available for the current year:				
Aircraft in commerce.....	101, 600. 00	85, 345. 78	16, 144. 71	109. 51
Air navigation facilities.....	97, 450. 00	86, 076. 18	10, 996. 87	376. 95
Incidental expenses of Army.....	29, 042. 00	26, 581. 87	2, 271. 47	188. 66
National Advisory Committee for Aeronautics.....	46, 000. 00	45, 205. 38	764. 44	30. 18
Materials and miscellaneous expenses, Bureau of Engraving and Printing.....	15, 000. 00	13, 260. 42	1, 714. 15	25. 43
Air Corps, Army.....	14, 950. 00	12, 497. 66	2, 434. 96	17. 38
Signal Service of Army.....	1, 800. 00	1, 610. 53	180. 43	9. 04
Aviation, Navy.....	78, 200. 00	72, 172. 28	5, 810. 07	217. 65
Export industries, Bureau of Foreign and Domestic Commerce.....	2, 640. 00	2, 610. 73	11. 89	17. 38
Gages, dies, and jigs for manufacture.....	2, 800. 00	2, 424. 99	361. 90	13. 11
Ordnance service and supplies, Army.....	2, 555. 00	2, 281. 63	250. 00	23. 37
General expenses, Coast and Geodetic Survey.....	100. 00	45. 15	-----	54. 85
Engineering, Bureau of Engineering.....	4, 000. 00	3, 199. 90	744. 15	55. 95
Contingent expenses, Coast Guard.....	2, 000. 00	1, 733. 18	264. 24	2. 58
Cooperative construction of rural post roads.....	4, 500. 00	3, 065. 28	1, 407. 87	26. 85
Contingent expenses, Steamboat Inspection Service.....	1, 000. 00	-----	909. 35	90. 65

(Footnotes at end of table.)



TABLE 4.—Disbursements, liabilities, etc., 1930, 1929, and 1928 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
<b>1930</b>				
Appropriations transferred from other departments which are available for a period of two years:				
Ordnance and ordnance stores.....	\$15,000.00	\$10,676.00	\$57.17	\$4,266.83
<b>Total.....</b>	<b>2,938,467.62</b>	<b>2,761,225.30</b>	<b>167,617.56</b>	<b>9,624.76</b>
<b>1929</b>				
Salaries.....	648,146.00	643,702.38		4,443.62
Equipment.....	<sup>8</sup> 88,014.11	87,779.58	22.32	212.21
General expenses.....	<sup>9</sup> 71,761.60	70,418.07	300.50	1,043.03
Improvement and care of grounds.....	14,431.00	14,407.25	9.65	14.10
Testing structural materials.....	<sup>10</sup> 268,653.68	261,982.99	34.00	6,636.69
Testing machines.....	41,003.00	40,288.99	7.50	706.51
Metallurgical research.....	51,614.00	49,213.14	14.00	2,386.86
Investigation of optical glass.....	27,420.00	27,067.00		353.00
Standard materials.....	10,824.00	10,657.41		166.59
Investigation of textiles.....	54,144.00	54,101.98		42.02
Sugar standardization.....	<sup>11</sup> 61,027.00	60,682.90	228.19	115.91
Gauge standardization.....	40,713.00	39,965.72	32.34	714.94
High-temperature investigation.....	10,401.00	9,321.28	95.00	984.72
Testing railroad scales.....	49,085.00	48,681.87	3.65	399.48
Investigation of fire-resisting properties.....	30,213.00	29,628.46		584.54
Testing miscellaneous materials.....	47,125.00	46,987.53	5.00	132.47
Investigation of public-utility standards.....	<sup>12</sup> 107,715.19	106,256.31		1,458.88
Radio research.....	<sup>13</sup> 56,429.03	56,324.85		104.18
Industrial research.....	<sup>14</sup> 205,679.78	204,078.73	57.50	1,543.55
Sound investigation.....	11,469.00	11,297.45	6.00	165.55
Investigation of clay products.....	49,370.00	46,629.84		2,740.16
Color standardization.....	10,950.00	10,930.39		19.61
Investigation of radioactive substances and X rays.....	31,741.00	31,283.67	20.85	436.48
Standardizing mechanical appliances.....	29,677.00	28,194.66		1,482.34
Investigation of mine scales and cars.....	13,688.00	13,472.39	10.00	205.61
Standardization of equipment.....	<sup>15</sup> 192,584.51	187,836.62	3.00	4,744.89
Automotive engines.....	26,833.00	26,434.97		398.03
Utilization of waste products from the land.....	53,148.00	49,137.84	161.88	3,848.28
Investigation of dental materials.....	5,421.00	5,257.77		163.23
Power-plant equipment.....	100,000.00	99,959.00		41.00
Testing structural materials, 1929-30.....	12,500.00	10,928.57	1,164.66	406.77
Appropriations transferred from other departments which are available for the current year:				
Aircraft in commerce.....	<sup>16</sup> 140,360.00	140,290.36	52.60	17.04
Party expenses, Coast and Geodetic Survey.....	2,000.00	1,927.73		72.27
Incidental expenses of Army.....	10,000.00	9,970.13		29.87
National Advisory Committee for Aeronautics.....	43,372.15	42,389.91		982.24
Air Corps, Army.....	11,500.00	11,487.22		12.78
Signal Service of Army.....	1,800.00	1,781.94		18.06
Materials and miscellaneous expenses, Bureau of Engraving and Printing.....	15,000.00	14,853.15		146.85
Aviation, Navy.....	66,140.00	66,031.51	2.10	106.39
Export industries, Bureau of Foreign and Domestic Commerce.....	2,640.00	2,615.26		24.74
General expenses, Coast and Geodetic Survey.....	200.00	200.00		
Air navigation facilities.....	15,700.00	15,647.86	33.60	18.54
Appropriations transferred from other departments which are available for a period of two years:				
Gages, dies, and jigs for manufacture.....	2,750.00	2,026.67	500.00	223.33
Ordnance stores, ammunition, 1929-30.....	1,000.00	939.01	57.65	3.34
Ordnance and ordnance stores.....	12,000.00	11,644.00		356.00
Safeguarding dome of rotunda, 1929-30.....	3,000.00	2,700.03		299.97
Automatic rifles, 1929-30.....	2,555.00	2,080.62	250.00	224.38
<b>Total.....</b>	<b>2,751,798.05</b>	<b>2,709,495.01</b>	<b>3,071.99</b>	<b>39,231.05</b>
<b>1928</b>				
Salaries.....	572,060.00	571,685.41		374.59
Equipment.....	88,000.00	87,784.10		215.90
General expenses.....	<sup>17</sup> 71,856.36	71,000.89		855.47
Improvement and care of grounds.....	13,000.00	12,883.53		116.47
Testing structural materials.....	<sup>18</sup> 241,897.38	241,161.26		736.12
Testing machines.....	<sup>19</sup> 38,025.00	37,753.37		271.63
Metallurgical research.....	<sup>20</sup> 48,414.92	48,229.18		185.74
Investigation of optical glass.....	20,520.00	20,457.48		62.52
Standard materials.....	10,000.00	9,922.19		77.81
Investigation of textiles.....	40,700.00	40,462.49		237.51

(Footnotes at end of table.)

TABLE 4.—Disbursements, liabilities, etc., 1930, 1929, and 1928 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1928				
Sugar standardization.....	<sup>21</sup> \$50,960.00	\$50,692.40	-----	\$267.60
Gauge standardization.....	38,320.00	38,214.76	-----	105.24
High-temperature investigation.....	9,740.00	9,732.09	-----	7.91
Testing railroad scales.....	47,000.00	46,974.92	-----	25.08
Investigation of fire-resisting properties.....	28,100.00	27,821.02	-----	278.98
Testing miscellaneous materials.....	44,000.00	43,899.84	-----	100.16
Investigation of public-utility standards.....	<sup>22</sup> 100,282.46	100,014.23	-----	268.23
Radio research.....	49,800.00	49,669.96	-----	130.04
Industrial research.....	<sup>23</sup> 175,860.00	175,411.69	-----	448.31
Sound investigation.....	10,580.00	10,517.65	-----	62.35
Investigation of clay products.....	47,000.00	46,579.21	-----	420.79
Color standardization.....	10,000.00	9,829.64	-----	170.36
Investigation of radioactive substances and X rays.....	29,540.00	29,433.33	-----	106.67
Standardizing mechanical appliances.....	27,800.00	27,633.33	-----	166.67
Investigation of mine scales and cars.....	12,800.00	12,750.64	-----	49.36
Standardization of equipment.....	<sup>24</sup> 130,135.50	130,091.49	-----	44.01
Automotive engines.....	<sup>25</sup> 27,700.00	27,345.94	-----	354.06
Utilization of waste products from the land.....	50,000.00	49,732.27	-----	267.73
Investigation of dental materials.....	5,000.00	4,983.60	-----	16.40
Power-plant equipment.....	100,000.00	99,911.23	-----	88.77
Sugar standardization, 1928-29.....	25,000.00	24,906.21	-----	93.79
Standardization of equipment, 1928-29.....	15,000.00	14,923.59	-----	76.41
Radio research, 1928-29.....	30,000.00	29,944.20	-----	55.80
Salaries, 1928-29.....	35,000.00	34,939.73	-----	60.27
Color standardization, 1928-29.....	5,000.00	4,341.63	-----	658.37
Furnaces and shelter, 1928-29.....	22,000.00	21,990.33	-----	9.67
Appropriations transferred from other departments which are available for the current year:				
Aircraft in commerce.....	110,000.00	105,693.51	\$138.29	1,168.20
Incidental expenses of Army.....	10,000.00	9,910.79	-----	89.21
Compensation of employees, Bureau of Engraving and Printing.....	11,000.00	10,913.94	-----	86.06
Export industries, Bureau of Foreign and Domestic Commerce.....	2,820.00	2,765.82	-----	54.18
National Advisory Committee for Aeronautics.....	34,900.00	34,605.16	-----	294.84
Aviation, Navy.....	77,500.00	76,727.01	5.00	767.99
Air Corps, Army.....	2,500.00	2,419.00	-----	81.00
Signal Service of Army.....	1,800.00	1,695.42	-----	104.58
Air navigation facilities.....	234.50	234.50	-----	-----
Appropriations transferred from other departments which are available for a period of two years:				
Ordnance and ordnance stores.....	12,000.00	11,775.44	-----	224.56
Ordnance stores, ammunition, 1928-29.....	1,000.00	951.06	20.35	28.59
Air Corps, Army.....	500.00	425.71	-----	74.29
Automatic rifles, 1928-29.....	2,000.00	1,836.63	150.00	13.37
Gages, dies, and jigs for manufacture.....	2,750.00	2,616.62	-----	133.38
Total.....	2,540,096.12	2,529,195.44	313.64	10,587.04

Includes reimbursements and transfers received from other departments as follows:

<sup>1</sup> \$1,790.49.	<sup>8</sup> \$14.11.	<sup>15</sup> \$461.51.	<sup>22</sup> \$282.46.
<sup>2</sup> \$4,193.51.	<sup>9</sup> \$1,906.60.	<sup>16</sup> \$360.	<sup>23</sup> \$3,540.
<sup>3</sup> \$52.32.	<sup>10</sup> \$1,595.68.	<sup>17</sup> \$2,001.36.	<sup>24</sup> \$135.50.
<sup>4</sup> \$3,900.	<sup>11</sup> \$2,800.	<sup>18</sup> \$1,897.38.	<sup>25</sup> \$2,700.
<sup>5</sup> \$133.30.	<sup>12</sup> \$418.19.	<sup>19</sup> \$25.	
<sup>6</sup> \$3,000.	<sup>13</sup> \$657.03.	<sup>20</sup> \$274.92.	
<sup>7</sup> \$15.	<sup>14</sup> \$2,052.78.	<sup>21</sup> \$2,800.	









